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APPLIED MECHANICS REVIEWS

VOL. 8, NO. 10 **MARTIN GOLAND** *Editor* OCTOBER 1955

ESSENCE OF DESIGN OF EXPERIMENTS

R. L. BROWN[1]

1 INTRODUCTION

An experiment should be planned to bring into prominence those factors it is desired to study and to enable their effects to be assessed in relation to the unavoidable errors of experimentation. Using modern statistical methods, based on those originally developed in the agricultural sciences, this purpose may be achieved with economy of effort. But to use the statistical method effectively, it is necessary for the engineer to be clear on what he wants to know and to appreciate the implications of the experimental design offered him by the statistician.

2 SIMPLE COMPARATIVE EXPERIMENT

It will simplify the presentation if the reader will agree to be the engineer and the writer the statistician. Then, reader, you tell me that you have been studying the effect of two paints on the resistance to corrosion of steel sheet. In order to eliminate differences in the finish between one sheet and the next, squares cut from each sheet were coated with the two paints. On repeating your measurements (by carrying out this procedure with several sheets) you found that the variability of the difference in resistance between the two squares from each sheet was high. You want to know how many further tests should be made to settle the question of which paint is the better.

I can tell you how much *replication*[2] you need. To do so, I make the assumption that straightforward statistical theory can be used and therefore require your measurements to be independent of each other. This would be the case if you had *randomized*[3] the order in which your experiments were carried out, so as to eliminate from the calculations any differences arising from uncontrolled variations in the finish of the sheets, or other changes from day to day. For example, if you had a number of batches of sheets, successively having a better finish, and if the efficiency of coating the squares with paint were also increasing, you should have arranged the sheets in random order—otherwise sheets of increasingly better finish would have been treated with increasing efficiency and your experiment would have been useless. Even when you do not know of a systematic change in finish, you must randomize in case it is there. If I cannot assume that straightforward statistical theory may be used, a more complicated experiment must be carried out.

I approve of your method of painting two squares from each sheet, the squares being taken from random positions on the sheet. This eliminates the variation from sheet to sheet, which might be large in relation to the effect of the paints, in which case you would not be able to find an answer to your question. This method of arranging the experiments in what are called *blocks* is very important and is used in more complicated experiments. Within each of your blocks there is a strict comparison of what it is you want to find out: in other words you have brought into prominence the object of your experiment. The variation between blocks (that is, from sheet to sheet) could also be found, but it need not be mixed up with the effect of the paints.

To analyze your data I make the null hypothesis that there is no effect due to the quality of the paints. Then I look to see whether the observed effect, considered in relation to the experimental errors, could have arisen by chance. If it could, the null hypothesis is justified and it may be concluded that the resistance of steel sheet to corrosion is not affected by the quality of the paints used. If it could not, it may be concluded that the effect is significant. In the latter case I estimate the magnitude[4] of the effect (if the experiment has been properly planned) and attach tolerance limits to this magnitude. You see how useful it is to plan the experiment so as to be able to estimate the errors.

In the space at my command, I cannot go into details of how your simple experiment can be elaborated to allow for a more complicated situation. Nothing new in principle is introduced; roughly speaking, the experiment is arranged in blocks; within blocks, the comparison you wish to make can be made; between blocks, extraneous or irrelevant factors are placed. Thus the experimental design is partly systematic and partly random. By randomization, unknown systematic variations of the experimental material are transformed into independent and random variations in relation to the treatments.

So when I talk about more complicated block designs, you can be sure that I am only elaborating your method of painting two squares from each sheet; my objective is an experimental design that renders the comparisons you want to make as clear as possible.

3 TWO-WAY PATTERN AND INTERACTION

The pattern of the experiment we have just discussed is shown in Table 1; in order to find the effect of paint freed from the differences between sheets, the data in the last column are analyzed. This is the comparison within blocks. Remember that you did not seek to find the effect from sheet to sheet.

[1] Director of Research Laboratories, British Coal Utilisation Research Association, Randalls Road, Leatherhead, Surrey, England.

[2] *Underlined* words refer to technical terms used by statisticians; in this article their meaning is indicated by implication only.

[3] For example, by tossing a coin; or better, by means of a table of random numbers.

[4] It is the mean of the last column of Table 1.

Simple Comparative Experiment

TABLE 1 REPLICATION OVER SHEETS TO DETERMINE DIFFERENCE DUE TO TWO PAINTS

	Resistance of steel sheet to corrosion Paint p^0	Paint p^1	Difference of p^0, p^1
Row 1	.	.	.
Row 2	.	.	.
Row n	.	.	.

Suppose now you wish to study the effect of two paints and of two finishes (in this case the finishes are known to differ) on resistance to corrosion. You have one sheet of each finish; you cut the first sheet into squares, choose two of these at random and apply the two paints; similarly with the other sheet. Then you have obtained the two-way pattern shown in Table 2: there are two factors: paint p, and finish f.

TABLE 2 TWO-WAY PATTERNS; TWO FACTORS (FINISH, f, AND PAINT, p)

		Resistance of steel sheet to corrosion Column 1 Paint p^0	Column 2 Paint p^1
Row 1	Finish f^0	A	B
Row 2	Finish f^1	C	D

I use the symbol P to denote the effect of factor p, F the effect of factor f (that is, the effect of changing from the low *level* f^0 of finish f to the high level f^1). Then, comparing with Table 1, the difference of columns 1 and 2 gives P, and of rows 1 and 2 gives F.

The meaning of P found in the second experiment (Table 2) is not the same as in the first (Table 1). The latter was derived from replication over several sheets having (ostensibly) the same finish, the former from replication over different finishes. Perhaps you can think out what this means.

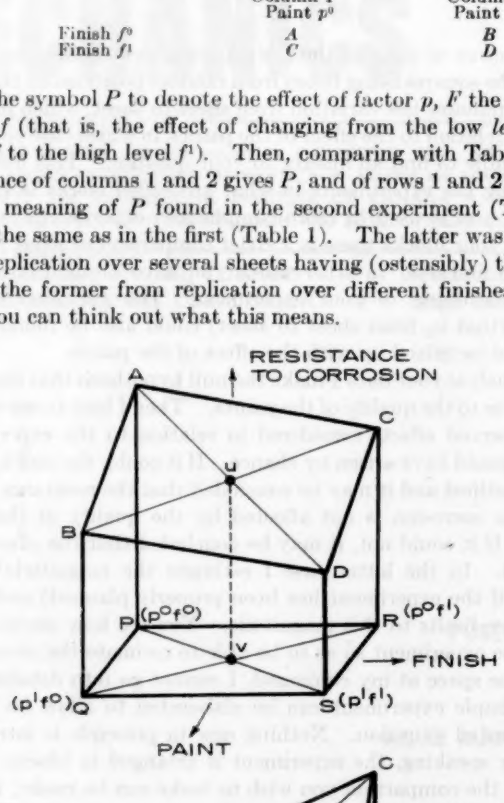

Fig. 1 Factorial experiment. Two factors at two levels
(a) top: *ABCD* coplanar; no interaction
(b) bottom: *ABCD* a tetrahedron: interaction

In Fig. 1a you see in the horizontal plane the pattern P, Q, R, S of the experiments (p^0f^0, p^0f^1, p^1f^0, p^1f^1). The points A, B, C, D in the third dimension indicate resistance to corrosion. The effect P is the mean of (BQ-AP), (DS-CR); it is pooled over both finishes f^0, f^1. The effect F is the mean of (CR-AP), (DS-BQ).

If the effect of paint is not the same for the two finishes, there is an *interaction*, denoted by PF. If there is no interaction, $ABCD$ are coplanar (assuming the errors to be negligibly small) and AD, BC meet in a point U situated over the center V of the pattern (Fig. 1a). If there is interaction, $ABCD$ is a tetrahedron and the midpoints U, U^1 of AD, BC do not coincide (Fig. 1b).

If the errors are not known from earlier experiments, they may be determined by replication. If you replicate, you still have the advantage that the design in Table 2 is more economical than an experiment in which you examine each factor separately (the "one factor at a time" method). It is also a wiser experiment in that it allows you to take care of interactions. Another advantage may be mentioned: the effect of one factor is assessed as a mean over a wide range of levels of the other factors and as such is often more useful.

Even when you know there is no interaction, the points A, B, C, D will not lie exactly in a plane; the discrepancies enable me to estimate the errors. Admittedly with only two factors at two levels (and two effects F and P to be found), I do not obtain a very reliable estimate. But if you know that the interaction PF is not real, an estimate of errors is available. Obviously Table 2 can be extended to cover as many rows and columns as you wish[5] and, in this case, the estimate of the errors becomes more reliable.

However the errors are found, you should know that in testing the significance or otherwise of the effects, I assume that the magnitude of the errors is not influenced markedly by the paints or by the finishes of the steel. Scrutiny of the method of carrying out the experiment and of the data obtained, in the light of past experience, are usually sufficient to settle whether or not the assumption is valid.

You notice that in the two-way pattern, each measurement contributes information on both the effects studied. This is the key to many of the more complicated experimental designs.

4 FACTORIAL EXPERIMENT

You say that your firm has asked you to carry out some experiments to decide whether to pretreat steel sheet before painting it. Your supplier is able to deliver two qualities of steel; two pretreatments are available to you and you have two paints to apply. Which combination is the best? You are also concerned with the variability in the supply of sheet from batch to batch and with the uncertainty with which the resistance to corrosion is measured. It seems to you that you will have to make rather a lot of experiments and you have not much in the way of facilities or time available for this purpose.

I think this is a case where you should begin by carrying out a factorial experiment in which every measurement can give you information relating to every one of the points which you have mentioned, rather in the way that I showed you just now with two factors. I suggest that you take sheets from two batches so that you will have a measure of the change from batch to batch.

You can choose one of several ways in which you can take account of the uncertainty of the measurement of corrosion. Thus, for one quality of steel you can take a sheet from one batch, cut it into several squares, pretreat four of them by one method, four by other method; use one paint on two of the first four squares, the other paint on the other two; and then do one corrosion meas-

[5] Then Fig. 1 is accurate only in some important special cases. Interaction retains the primary meaning given above.

urement on each square: in this case the difference between corrosion measurements will include also any difference there is between different squares from the same sheet. Another way would be to take two sheets, a, b from each batch, cut them into squares and take two squares from each sheet for test; pretreat a's squares by one method and b's by the other; then use the two paints on a's squares; then on b's squares; and then make one measurement on each square: here the uncertainty of the corrosion measurement will be combined with the difference between sheets within batches.

You must choose which method best suits your purpose. In any case you have to make 32 measurements. One reason why I like this factorial arrangement is that the arithmetic needed in analyzing the results is rather simple.

Your experiment is a factorial experiment on five factors each at two levels.[6] I can find the five main effects, that is, the effect of each factor, pooled over the whole range of conditions which you have covered in your tests. I can also find the ten first-order interactions, that is, all the interactions between each factor taken with every other factor. There are also higher-order interactions; for example, the effect of pretreatment on the two steels might be different for the different paints, and so on. I want you to think about these higher-order interactions. It is likely that they correspond to real effects; or can they be attributed solely to the experimental error? Supposing that they can, then I can combine all these higher-order interactions together and use them as an estimate of the error of the experiment: then replication is not needed. If only main effects and first-order interactions are expected to be real, I obtain a quite reliable estimate of the experimental error. Thus I can test the significance of each of the main effects and each of the first-order interactions. If you cannot decide which interactions are not real, then we can replicate the experiment in order to find the errors: where the errors are suspected not to be homogeneous for the different levels of one or more factors, such replication is probably advisable.

In the light of the answers which we obtain, you can carry out life tests on your prepared sheets incorporating the more suitable combinations of the different factors and introducing the effects of atmosphere; e.g., between rural and urban areas, and any other factors you may desire to study. Again it is likely that we will do this by means of a factorial experiment.

In a factorial experiment it is not, of course, essential that there should be five factors, each at only two levels; the method I have described is perfectly general, provided that every entry in the pattern is obtained. In engineering, three and four level designs are often encountered.

In a so-called classical experiment the factors are studied one at a time. This requires more experiments than in a factorial design. A more serious issue is the implicit assumption that all first-order and all higher-order interactions are zero. In a factorial experiment you do not have to make this assumption and you proceed with your eyes open.

A word of warning: you arrange the experiment in a random way. Thus you choose two batches at random out of several batches. You take the sheets out of each batch at random. You cut the sheets up into several squares and choose squares at random for painting, and so on.

5 CONFOUNDING

You have seen that when you have to study the effects of several factors, it is possible that prior thought about the reality of interactions will enable us to economize in effort. Let us look again at Fig. 1. The interaction PF is got from the distance UU^1 where UV is $\frac{1}{2}(AP + DS)$, and U^1V is $\frac{1}{2}(BQ + CR)$. Thus VU is got from the experiments p^0f^0, p^1f^1 and VU^1 from p^0f^1, p^1f^0.

[6] Table 2 is a factorial experiment with two factors at two levels.

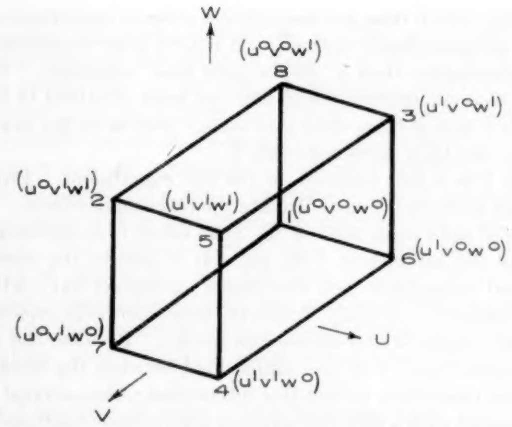

Fig. 2 Pattern of eight experiments with three factors each at two levels

(Between tests 1, 2, 3, 4, and 5, 6, 7, 8 the interaction UVW is confounded.)

The generalization of this division of the experiments to cases with more than two factors has great importance.

The pattern of eight experiments with three factors u, v, w at two levels is shown in Fig. 2. I divide (Table 3) the eight tests into two blocks, each having four members, 1 2 3 4 and 5 6 7 8.

TABLE 3 DIVISION OF EIGHT EXPERIMENTS ON THREE FACTORS AT TWO LEVELS INTO TWO BLOCKS CONFOUNDING THE SECOND-ORDER INTERACTION UVW

	1	2	3	4
	$u^0v^0w^0$	$u^0v^1w^1$	$u^1v^0w^1$	$u^1v^1w^0$
	5	6	7	8
Block 2.	$u^1v^1w^1$	$u^1v^0w^0$	$u^0v^1w^0$	$u^0v^0w^1$

In calculating the interaction UVW, I take the mean of block 1 from the mean of block 2.

Suppose now that it was convenient to you to carry out four of the eight tests in one week and the remainder two or three weeks later and you were concerned that unknown differences might be introduced into the experiment. This would not matter provided you randomized the order in which you carried out the eight tests; but the uncontrolled variations may be aggravated by the two-week interval, in which case the estimate of errors will be inflated.

Alternatively, you could follow the procedure (as we discussed in Section 2) of dividing into blocks and, in this case, the division into block 1 and 2 shown in Table 3 would be appropriate. Here all the effects, except the second order interaction UVW, are free from differences between blocks. The price you have paid is that the second order interaction cannot be distinguished from the difference between blocks: this may or may not be important, depending on circumstances. You have gained a more reliable (and usually a smaller) error term, so that the experiment is more sensitive. I describe this situation by saying that UVW is confounded with the block differences.

It should be noted that it is the division into the blocks shown above which leads to this useful result. My statistical colleagues have methods for confounding any effects or interactions between blocks in experiments with any number of factors at any number of levels. Some of these combinations are particularly convenient.

6 FRACTIONAL REPLICATION

You say that you can see how the methods we have been talking about have a clear use in agriculture, where the experimenter has to wait until the plants grow. But in industry, experiments are carried out as a sequence in time and you expect Monday's experiments to guide you in what you do on Tuesday. This is

quite right, but it does not mean that a series of experiments, each having an appropriate pattern, will not be more economical and more informative than a "follow your nose" approach. For example, you can analyze the results you have obtained in block 1 of Table 3 and, if these data give a clear lead as to the next step, you may not then carry out block 2.

Block 1 is a half replicate of the full experiment. From the four tests in block 1, I can calculate the three main effects. In the absence of data from block 2 the main effect U is indistinguishable from the interaction VW, etc. It is always the case in a fractional replication that the effects calculated have what are called "aliases." Usually, however, prior knowedge enables you to decide which of the aliases has reality. Because the second order interaction UVW was confounded between the blocks it is, of course, impossible to find this interaction unless several blocks are arranged with a different effect or interactions confounded between each pair of blocks.

Let us go back to your experiment with five factors at two levels: f = finish of steel, p = paint, u = pretreatment, v = batch, w = measurement. The full factorial experiment required 32 tests. You can arrange these 32 in four blocks of eight, each block being a quarter replicate. The first eight tests enable me to estimate the effects of each of the five factors and also of the interaction of one factor with each of two others. It is necessary that all other interactions be assumed to have no reality (otherwise the aliases cannot be sorted out) and that your earlier work has provided you with an estimate of the errors.

In your case you might arrange the experiment so as to obtain the interactions FP, PU, and the five main effects, F, P, U, V, W. It is hardly likely that any of the interactions with V and W can be real. The interactions UP, FUP, may or may not enter into your problem; can you say if it is likely that they are real? If not, we carry out the eight tests in the quarter replicate in random order. In the light of the results, you then decide whether or not to proceed with the eight tests in block 2.

7 REGRESSION AND OTHER RELATIONSHIPS

You say that you can see the principles behind the methods I have proposed to enable you to find out which factors, or combination of factors (interactions) influence the results of your experiments significantly and which have no effect. But in many cases this is not enough and you want to know also some form of quantitative relationship. For example, you have now found that only one factor (call it p) influences resistance to corrosion (call it r): how do I set about finding some simple equations to express this result? It is assumed, of course, that p and r are each recorded by a series of numbers, so that a graph of r vs. p can be drawn.

If the effect of p has been determined at s levels, then I can find a polynomial of degree $(s - 1)$ which will pass through all the observations. But, as you say, such a polynomial is unlikely to have engineering utility. I agree that this is not likely to be what you want. Let us suppose that when the data are plotted they do not depart markedly from a linear relationship. Then I can calculate what is called the regression line of r on p by minimizing the sum of squares of the deviations (measured parallel to the r axis) from a straight line.[7] This equation serves to predict r when p is given. In other words, p is supposed to be known precisely (that is, to be free from error). It can attach tolerance limits to the regression line if this is desired.

I must emphasize that this regression line is not to be interpreted as necessarily having either physical or engineering importance. If I reverse my procedure, and regard r as known precisely, I can calculate also a regression line of p on r. This second line predicts p for a given r. The two regression lines are not the same (unless the points lie exactly on a straight line).

[7] The calculation of a regression line from data obtained in a factorial experiment at several levels is particularly simple.

I make the point in the previous paragraph in order to show that it is for the engineer to decide in the light of his experience what form of relationship he wishes to have calculated, and whether this relationship is to be regarded as a convenient representation of the results or as an equation for prediction or whether deeper importance is to be ascribed to it. In other words, the engineer is to say which of his factors are to be regarded as dependent and which are to be regarded as independent. Fortunately in many cases you are able to do this.

It does happen, however, that you cannot always do this division into dependent and independent variables with any confidence. In such a case you have put me in a difficulty. There are methods of determining what are called *structural* relations in which all the factors are treated on an equal footing. But these methods are only useful when the outcome of the experiment is clear cut. These methods do not lead to an unequivocal *functional* relation, where by functional relaxation I mean such relations as Boyle's law or Ohm's law. When all the variables which enter into the law are subject to experimental error, there is no accredited body of statistical theory to be applied. This does not mean that the statistical design of experiments cannot be useful to you: whether or not you use these modern methods has got nothing to do with the fact that at present we cannot make a statistical test of a functional relationship. In physical science you would get out of the difficulty by refining your experiment until the validity or otherwise of a functional relationship is self-evident. In engineering science you may not be able to do this, and you have to go as far as you can.

8 OPTIMUM CONDITIONS

I have shown that if you arrange your experiment in part in a systematic pattern (so that each measurement contributes information about every effect you want to find) and in part at random (so that I can use with some confidence straightforward statistical theory), you can achieve economy in your experimental effort and I can give you precise answers to the questions that you ask.[8] I hope now that when you consult a professional statistican you will find a common language and be able to help each other.[9] You will have to take into account factors such as wear and tear of plant in a long series of trials, the effect of trends in processes and of changes in raw materials, and the fact that the errors may not be the same for all combinations of your factors (for example, as between low and high duty of a plant). The importance of these points and of others which readily come to mind has not been fully worked out; this is a task for the future.

An important recent development is the use of these methods for the determination of optimum conditions for the operation of a process. If you imagine the efficiency or the unit cost of the process to be plotted in multidimensional space, incorporating all the factors known to be relevant, then the curved space so obtained can have various types of maxima. You will have seen that it is not necessary to study the effect of each factor one at a time and, indeed, where interactions exist, it might be misleading to do so. Methods (deriving from what we discussed in section 6) are now available[10] that will enable you to move progressively toward the optimum operating condition, discarding as you go the unimportant factors and finding the nature of the peak on

[8] The examples I have given here have been chosen mainly to bring out the principles of experimental design and are unlikely to give you good designs to use in experiments you have to make.

[9] I recommend you ask him to explain the meaning of one of the important concepts that have not been introduced here, namely *degrees of freedom*. Also ask him to work an example out with you in detail.

[10] "Design and Analysis of Industrial Experiments," edited by O. L. Davies, Oliver and Boyd, 1954, Chapter 11.

which you land. Much remains to be done on experimental designs of this type, but there is little doubt that it is the most important development since statistical methods have come to be used in engineering science.

Any method of experimentation for finding optimum conditions of an existing process seeks a path which leads to a plateau. It should perhaps be mentioned that such investigations may not lead to a process having a different order of efficiency corresponding, for example, to a peak which can only be reached by passing through a deep valley. In other words, in development work, particularly that aimed at radical changes in processes, the more intuitive type of step-by-step experiment still has its place. The statistical method is a powerful tool to be used with discretion; it does not replace the older method of experimentation; they are complementary.

9 CONCLUSION

In writing the above, much has necessarily been omitted: thus no reference has been made to the *analysis of covariance* or to *sequential* tests of experimental data, and so on. I thought it best to concentrate on the ideas of interaction and confounding, which your colleagues often find difficult. You see that experimental design is quite simple in essence. It has to be thought out in advance and the professional statistician can help you to do this: he has powerful methods that insure that in the more complicated cases he has been logically consistent and is not making mistakes. But you have to know what you want. For maximum economy of experimentation you have to decide in the light of your experience what information can be dispensed with. In order to do this you have to know what the statistican is trying to do for you: to aid you in this has been the sole purpose of this article.

Now I can give up being a statistican and revert to being a research worker in physical and engineering science. Then I can assure you that the study of experimental design is rewarded by worth-while results.

A Report to Our Readers

Applied Mechanics Reviews will shortly enter its ninth year of publication. Affording its readers a critical appraisal of the current international literature in applied mechanics and related engineering science, the Reviews is today recognized to be an essential research and development tool of steadily increasing importance. The periodicals and special publications regularly scanned for review material now exceed 700 in number, and over 200 books are received annually from all parts of the globe. More than 1500 authorities from 30 countries contribute their services as reviewers.

During the past eight years, the Reviews has met and solved many of the varied problems which usually face a new and complex enterprise. The difficulties of starting operations "from scratch" have been overcome by hard and unceasing labor; new areas of engineering science are steadily being added; and valiant efforts are being made to maintain the comprehensive nature of the Reviews service in the face of an enormous and continuing increase in the volume of published material. Handicapped from the start by the practical necessity of limiting staff and budget, the measure of success achieved by the Reviews to date is a testimonial to all those who have labored far beyond their job requirements to further this service to the engineering profession.

The Reviews was brought into being as the result of a study financed by the Office of Naval Research, and The American Society of Mechanical Engineers subsequently agreed to assume publication responsibility. Although it has been hoped that the Reviews would rapidly become almost self-supporting through its subscription income, such hope, unfortunately, has not been realized, and the subscription income has stabilized at under 50 per cent of the operating expense. Nevertheless, publication has been continued in the face of substantial operating deficits only because various agencies have recognized the importance of the Reviews service and have backed up this conviction with financial support.

The ASME, through its Development Fund, has thus far invested over $80,000 in this enterprise, and substantial contributions have been received from the Engineering Foundation and the Research Corporation. Important portions of the editorial office expense have been borne by the Office of Naval Research, the Air Research and Development Command, and the National Science Foundation. Although such aid has been given wholeheartedly, it should be recognized that this aid can only be of temporary duration. An answer to the problem of stabilizing the financial basis of the Reviews operation must be found in the immediate future.

As a natural consequence of financial uncertainties, the Reviews has been unable to cope effectively with certain problems now pressing for decision. Only herculean efforts have enabled the staff to keep abreast of the growing tide of engineering science literature. Comprehensiveness is the mainstay of a review journal; if complete coverage is to be realized in the fields of interest to our readers, the Reviews staff must be enforced. Consequently, the current budget must not only be balanced, but an increasing rate of expenditure must be anticipated.

With these varied factors in mind, the management of the Reviews has decided that direct action must be taken to increase substantially the subscription income of the magazine. Accordingly, a new rate schedule is now being placed into effect. Annual subscriptions will be priced at $25, a 100 per cent increase over the present rate. ASME members will be permitted to receive the Reviews for an annual subscription price of $10, a slight increase over the present rate, with the understanding that such copies are to remain the personal property of the subscribing member. The rate for American reviewers is being advanced to $7.50 per year, again on the basis of personal retention of all copies. Reviewers outside the United States, as in the past, will be sent copies gratis in return for their mailing and other unusual expenses. Since the other engineering societies have reluctantly indicated their inability to share the financial responsibilities of the Reviews, special rate privileges to their memberships are, of necessity, being discontinued.

The urgent need for increasing subscription income cannot be too strongly emphasized to all those who wish to see the Reviews continued. Present subscribers must be retained, and new subscribers added. The new rates are modest in view of the value received, and the Reviews is not alone in finding it necessary to increase its rates; similar and even more drastic action is being taken by other abstract and review services.

Continuance of the Reviews rests in the hands of its users. Unless old and new subscribers rally to support the effort, this informational tool, designed to keep scientists and engineers in applied mechanics and related fields informed on a world-wide basis, will be unable to continue publication.

The Editor

Books Received for Review

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Switkowski, J., Textile Dictionary in 5 Languages, Warsaw, Państwowe Wydawnictwa Techniczne, 1955.

Sztompke, W., Geodetical Dictionary, Warsaw, Państwowe Przedsiebiorstwo Wydawnictwa Kartograficzynch, 1954. (Written in 5 languages.)

Trier, H., Die Kräftübertragung durch Zahnräder, Betriebsverhaltnisse, Abmessungen und Bauformen der Zahnräder in Vorgelegen und Umlaufgetrieben, Berlin, Springer-Verlag, 1955, 78 pp. DM 3.60 (paperbound).

Letters to the Editor

2942. Re AMR 8, Rev. 1311 (May 1955): M. Kuipers, Numerical calculation of the end-effect of cylinders, used as measuring element in load-cells.

Author does not relate the force on a load cell to strains, as reviewer states, but he analyzes the effects of a nonuniformly distributed load on the strain experienced by the axial strain gages. In this first approach to the general problem, the gages in circumferential direction were disregarded in order to avoid too great complexities in the calculations.

Reviewer's statement about the necessity of calibrating a load-cell in an accurate testing machine is true but bears no relation to the present paper, which was initiated at the request of some designers of load-cells wanting some data concerning the said problem and is, therefore, of more than theoretical value. It is granted that the problem has been approached in an approximate manner. The alternative, however, is to design without any numerical information. M. Kuipers, USA

Theoretical and Experimental Methods

(See also Revs. 2959, 2961, 2968, 2976, 2977, 2994, 2995, 2996, 2997, 3009, 3029, 3046, 3047, 3048, 3049, 3110, 3111, 3112, 3114, 3116, 3128, 3131, 3151, 3154, 3157, 3171, 3198, 3256)

2943. Flügge-Lotz, I., and Wunch, W. S., On a nonlinear transfer system, *J. appl. Phys.* **26,** 4, 484–488, Apr. 1955.

Authors examine, by phase-plane methods, desirable forms for spring and damping coefficients in a second-order position control system when they can be switched from one constant value to another by sign of error or error rate. A few examples are given but, as authors remark, the problem is not to transfer one input extremely well but many inputs equally well, and this line is not pursued. N. Ream, England

2944. Minorsky, N., On asynchronous action, *J. Franklin Inst.* **259,** 3, 209–219, Mar. 1955.

Paper investigates the nonlinear phenomena of asynchronous quenching and excitation of oscillations directly from the differential equations without the previously used tool of equivalent linearization. The equations are related to the van der Pol equation and a stroboscopic transformation is applied. Asymptotic instability accounts for the quenching, and the excitation depends on the transfer of the position of equilibrium across the bifurcation point. Thus the latter is observed only in "hard" systems, since the "soft" ones have no bifurcation point. Reviewer notes the β in Eq. (4) should be ψ.

J. D. Riley, USA

2945. Millington, G., A note on the solution of the sextic equation, *Quart. J. Mech. appl. Math.* **7,** part 3, 357–366, Sept. 1954.

Paper presents an indirect method for solution of the sextic equation with real coefficients. Method involves a rapidly convergent iteration requiring only one initial trial unknown. Final solution is obtained by solution of a cubic equation which may have complex coefficients. Author claims method compares with others in time and reduction to tabular forms.

J. B. Duke, USA

2946. Hestenes, M. R., Iterative computational methods, *Comm. pure appl. Math.* **8,** 1, 85–95, Feb. 1955.

One of the outstanding achievements in computational methods in recent years is the development of iterative schemes which solve, in n steps, n-dimensional problems, such as the equation system $Lx = b$ (L is an $n \times n$ matrix, x, b are n-element column vectors) or the eigenvalue problem $Lx = \lambda x$. While the appropriateness of $b, Lb, L^2b, \ldots, L^{n-1}b$ as base vectors for such problems (in terms of which the unknown x is expanded) has been indicated already by Friedrichs and Horvay in 1939 ["The finite Stieltjes momentum problem," *Proc. Nat. Acad. Sci.*, p. 528] incidental to their search for lower bounds to eigenvalues, the paper was entirely unnoticed. It was C. Lanczos' historic presentation at the Harvard Symposium on large-scale calculating machinery in 1949 which suddenly focused attention on this important approach, and touched off feverish activity in the field. Lanczos in his paper [AMR 4, Rev. 2339] develops the necessary recurrence formulas for the eigenvectors $x_1, x_2, \ldots, X_n$ of the eigenvalue problem in n steps. In practice the method, for n large, is unworkable because of accelerated loss of significant digits with each iteration, as caused by the bunching of the vectors L^kb in the direction of the highest eigenmode. (In fact, this bunching was the very reason for the success of the formerly used iteration method of Cayley-Sylvester-Vianello-Stodola-Frazer-Duncan-Collar, et al., for determining the highest mode.) Lanczos corrected the deficiency by introducing a modified procedure: orthogonalizing the base vectors L^kb. (He labeled the new vectors p_k: $p_0 = b$, $p_k \perp p_i$ for $k \neq i$.) Lanczos also set up a second system of base vectors g_k, and, in a second paper [AMR 6, Rev. 706], he showed that the vectors g_k are orthogonal with respect to the weight matrix L: $g_0 = b$, $g_k \perp Lg_i$ for $k \neq i$. Solution of the eigenvalue problem $Lx = \lambda x$ and of the equation system $Lx = b$ is particularly convenient when the base vectors p_k, g_k are used jointly. When n is so large that an n-stage iteration scheme is out of the question, then preliminary use of "Chebyshev polynomials in the solution of large-scale linear systems" [*Proc. Assoc. Computating Mach'y*, 1953], as proposed by Lanczos, may

sufficiently "condition" the matrix for the n-step method, so that all important information about the problem can be squeezed out of the process in a fraction of n steps. (A detailed digest of Lanczos' three papers is contained in *KAPL Rep.* 1004, Office of Technical Service, U. S. Government Printing Office, Washington, D. C., 70 cents.) E. Stiefel in his paper "Über einige Methoden der Relaxationsrechnung" [*ZAMP*, p. 1, 1952] investigates the phenomenon of drift in relaxation estimates and, incidental to this interesting study, establishes many of the formulas Lanczos lists in his second paper. Summarizing the development of the n-step method, Hestenes and Stiefel in their paper "Method of conjugate gradients for solving linear systems," *J. Res. nat. Bur. Stds.* 1952, p. 409, review past efforts by Hestenes, Rosser, Forsythe, Paige at Los Angeles, Stiefel in Zürich, and Lanczos at Seattle and Los Angeles, to develop n-step iteration schemes, offer some refinements to the established methods, and investigate questions of convergence, error propagation, relation to other methods; they also survey numerical results.

The paper under review is a review paper on recent developments in iterative computational methods, with particular emphasis on gradient methods, conjugate gradient method, sources of errors, eigenvalue problems. While the author states that "no attempt is made to survey the literature on these subjects," it was somewhat of a shock to note that Lanczos' name is not included in the bibliography. G. Horvay, USA

2947. Ludwig, R., Iterative solution of equations and systems of equations. Part II (in German), *ZAMM* **34,** 10/11, 404–416, Oct./Nov. 1954.

The results developed in part I [AMR 8, Rev. 1258] for the case of a single equation in one unknown are here extended to the case of n equations in n unknowns. F. L. Alt, USA

2948. de Vogelaere, R., A method for the numerical integration of differential equations of second order without explicit first derivatives, *J. Res. nat. Bur. Stands.* **54,** 3, 119–125, Mar. 1955.

This is a fourth-order step-by-step method based on difference formulas. The case of a single equation is discussed in detail. The use of this method for an automatic computer is considered.

From author's summary

2949. Jaeckel, K., Solution of the Ackermann-Birnbaum integral equation with the aid of an interpolation formula (in German), *Z. Flugwiss.* **3,** 2, 46–48, Feb. 1955.

The chordwise vorticity distribution $\gamma(\xi)$ of thin-wing theory is obtained by solving integral equation

$$\frac{1}{2\pi}\int_{-a}^{a}\frac{\gamma(\xi)}{\xi - x}\,d\xi = \nabla y^1(x), \quad -a < x < +a \qquad [1]$$

where $\nabla y^1(x)$ is given. Putting $\xi = a\cos\psi$, $x = a\cos\phi$, [1] becomes

$$\frac{1}{2\pi}\int_0^{\pi}\frac{\Gamma(\psi)d\psi}{\cos\phi - \cos\psi} = Y^1(\phi) \qquad [2]$$

where $\Gamma(\psi) = \gamma(a\cos\psi)\sin\psi$, $Y^1(\phi) = \nabla y^1(a\cos\phi)$.

Taking note of the well-known Glauert integral formula

$$\frac{1}{\pi}\int_0^{\pi}\frac{\cos n\psi}{\cos\phi - \cos\psi}\,d\psi = -\frac{\sin n\phi}{\sin\phi}, \quad (n = 0, 1, 2,\ldots) \qquad [3]$$

it is easily seen that by expanding $Y^1(\phi)$ into Fourier series

$$Y^1(\phi)\sin\phi = \frac{1}{2}\sum_1^{\infty} b_n \sin n\phi$$

we obtain, through [2], [3]

$$\Gamma(\psi) = \frac{1}{2}b_0 + \sum_1^{\infty} b_n \cos n\psi \qquad [4]$$

Thus we finally arrive at the Fourier expansion for vorticity distribution $\gamma(\xi)$ as follows

$$\gamma(\xi) = \gamma(a\cos\psi) = \frac{\Gamma(\psi)}{\sin\psi} = (1 - \xi^2/a^2)^{-1/2}\left(\frac{1}{2}b_0 + \sum_1^{\infty} b_n \cos n\psi\right) \qquad [5]$$

Author introduces a scheme which is slightly different from above, and claims that it works more directly, in the following way: By first integrating equation [1], a relationship between Fourier coefficients of $\gamma(x)$ and $y(x)$ is established (which can easily be deduced from [4]). One can then proceed directly to the determination of Fourier coefficients for $\gamma(x)$ as integrals involving $y(x)$ itself, without going through the intermediate steps of carrying out the Fourier expansion for the latter.

Reviewer believes, however, that author's claims can hardly be substantiated. Indeed, a little reflection reveals that in the process of evaluating $\gamma(x)$ described above, Fourier expansion for $y(x)$ is never actually carried out. In fact, if in [4] we put explicitly

$$b_n = 2\,{}_0\!\int^{\pi} Y^1(\phi)\sin\phi\sin n\phi\,d\phi \qquad [6]$$

we immediately recognize the identity between the two schemes Nevertheless, author did succeed in obtaining an interpolation formula to replace integral [6], which, although of little theoretical interest, should prove welcome to practical aerodynamicists.

H. S. Tan, USA

2950. Hallen, E., Further investigations into iterated sine- and cosine-integrals and their amplitude functions with reference to antenna theory, *Trans. roy. Inst. Technol. Stockholm* no. 89, 42 pp., 1955.

Paper investigates the functions $L(x) = {}_0\!\int^x (1 - e^{-iu})\,du/u$, ${}_0\!\int^x L(n)du/u$, ${}_0\!\int^x e^{iu}L(u)du/u$, etc. Series expansions both convergent and asymptotic are developed. Tables are presented, mostly to 6d. Applications to author's antenna theory are indicated in paper and its bibliography.

Y. L. Luke, USA

2951. Liebmann, G., The solution of plane stress problems by an electrical analogue method, *Brit. J. appl. Phys.* **6,** 5, 145–157, May 1955.

Biharmonic equation $\nabla^4\chi = 0$ and similar equation $\nabla^4\chi = f(x, y)$, with boundary conditions commonly specifying x and normal gradient $\partial\chi/\partial n$, are solved using analog machine comprising two resistance networks in cascade. Solution is not obtained directly, as in corresponding network for the Laplace equation, but rapidly convergent iterative adjustments are made to boundary voltages in upper network whose junction voltages correspond to values of $\nabla^2\chi$, to satisfy both boundary conditions belonging to lower network whose junction voltages give χ. Individual stresses are obtained by numerical differentiation. Paper gives full details of construction, error analysis, and techniques for obtaining best possible accuracy of 1 to 2% in stresses. Illustrative examples compare results with analytical solution to simple prob-

lem and photoelastic solution with more complicated loading conditions and curved boundaries. This apparatus is relatively cheap, and reviewer considers it very useful for problems of this kind, not easily solved by hand or, at present, by high-speed digital computers.

L. Fox, England

2952. Gradwell, C. F., and Kaye, J., Electronic calculation of critical whirling speeds, *Engineer, Lond.* **199,** 5171, 294–296, Mar. 1955.

Some of the work on the computation of critical speeds of rotor systems that has been done on the Ferranti electronic digital computer at Manchester University is described here. The mathematical method is described, and some explanation is given of how the computer is used to carry out the computation.

From authors' summary

2953. Händler, W., Nomographibility of higher functions (in German), *ZAMM* **34,** 8/9, 293–294, Aug./Sept. 1954.

Conditions are given for certain nomographical representations of a function of one complex variable. Application of the results is made to the representation of elliptic functions.

H. Witting, Germany

2954. Dreĭnes, M. A., and Aĭzenshtat, N. D., Possibility of nomography of highest degree of accuracy (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **95,** 6, 1137–1140, Apr. 1954.

$z = z(x,y)$ is nomographic at scale points (x_0, y_0, z_0) if (1) point x_0 of scale x, point y_0 of scale y, and point z_0 of scale z are collinear; (2) no two points of (x_0, y_0, z_0) coincide; and (3) the solution line of the nomograph is not in the osculating plane of the answer scale, z.

Let scale functions $u = X_1(x)$, $v = X_2(x)$, $u = Y_1(y)$, $v = Y_2(y)$, $u = Z_1(z)$, $v = Z_2(z)$ give scales for x, y, z. At (x_0, y_0, z_0) the value of the determinant which has rows $X_1, X_2, 1$; $Y_1, Y_2, 1$; and $Z_1, Z_2, 1$ is zero. Put scale functions $X_1 = a_{1i}x^i$, $X_2 = a_{2i}x^i$,. . . . etc., with $a_{1i}, a_{2i}, \ldots$, undetermined coefficients. Let r be the radius vector of the neighborhood of z_0. Function $\acute{z} = z(x, y)$ is nomographic in the neighborhood of z_0 to accuracy of $0\ (r^k)$, $(\imath \leq k)$ when coefficients $a_{1i}, a_{2i}, \ldots$ are constrained by the determinantal equation row $a_{1i}x^i, a_{2i}x^i, 1$; $b_{1i}\,y^i, b_{2i}\,y^i, 1$; and $c_{1i}\,z^i, c_{2i}\,z^i, 1$; equal infinitesimal $0(r^k)$.

K. D. Saunders, USA

2955. Zimmerman, O. T., and Lavine, I., Conversion factors and tables, 2nd ed., Dover, N. H., Industrial Research Service, Inc., 1955, 501 pp.

This book is a time-saver. It provides an accurate source of fundamental physical relationships as well as several thousand useful constants for the conversion of units. It is not merely a compilation of material from various sources. Large-faced, legible type with sufficiently spaced lines is of great value for easy reading. New features of the 2nd edition are: (1) An expanded conversion factor section in which all values have been recalculated, based on the latest accepted fundamental values; (2) a section on conversion factors for most of the foreign countries of the world, which are difficult to find in any publication; (3) a section of foreign monetary equivalents; (4) a table of physical constants; (5) 14 new conversion tables have been added.

Unique handy book contains: Definition of fundamental values; physical constants; conversion factors—U.S., British, metric; foreign conversion factors; foreign monetary equivalents. Conversion tables contain: mensuration; temperature; thermocouple tables—millivolts to Centigrade and Fahrenheit, for copper-constantan, iron-constantan, chromel-alumel, platinum-10% rhodium, and platinum-13% rhodium; pressures of water at various temperatures; vapor pressures; hydrometer conversion formulas for various specific gravities; weights of sugar solution at −20 C; A.P.I. gravity factors; viscosity conv. formulas; Gardner-Holdt letter definitions of viscosity reference standards; color scale conversions for liquids; hardness conversions (also Mohs' scale) in general, for hardened and unhardened steel, and for nonferrous metals and alloys; wire and sheet metal gages; decimal equivalents; five-place common logarithms.

J. J. Polivka, USA

2956. Ehrich, F. F., Differentiation of experimental data using least squares fitting, *J. aero. Sci.* **22,** 2, 133–134, Feb. 1955.

Note in Readers' Forum. Recent discussion has centered on the problem of numerical differentiation of experimental data. Simplified formulations have been offered for finding the derivatives at the central point of an odd number of uniformly spaced points. These formulations derive from fitting high-order polynomials to the given points and taking the derivatives at required points.

It is proposed that a technique less sensitive to experimental error involves fitting a low-order polynomial to the experimental points by means of the method of least squares. The derivatives of the low-order polynomial are then a reasonable approximation to the derivatives of the experimental data and should reduce sensitivity to experimental error. From author's summary

2957. Emmons, H. W., and Leigh, D. C., Tabulation of the Blasius function with blowing and suction, *Aero. Res. Counc. Lond. curr. Pap.* no. 157, 78 pp., 3 figs., June 1953, published 1954.

Authors tabulate solutions of $f''' + ff'' = 0$ for the velocity distribution in a boundary layer. For each solution $f'(0) = 0$, $f'(\infty) = 2$. The third boundary condition is the specification of $f(0)$. $f(\eta)$ and its first three derivatives are tabulated to 5d in gaps of 0.1 in η for $f(0) = -1.23849$, $-1.2\ (0.05)\ 0.5\ (0.1)\ 1.5$, 2, 2.5, 3 (1.0) 6, 10. Tabulation extends to η_1 where $f'(\eta_1) = 2.0$, $f''(\eta_1) = 0$ to 5d. Introduction gives method of solution and physical meaning of boundary conditions, etc. Lock's [AMR 4, Rev. 3642] solution of a laminar jet mixing problem is discussed.

Y. L. Luke, USA

2958. Schmidbauer, H., Developable surfaces. A study for the practical designer [Abwickelbare Flächen. Eine Konstruktionslehre für Praktiker], Berlin, Springer-Verlag, 1955, v + 66 pp., 80 figs. DM 6.60.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 2973, 2975, 2987, 2989, 2990, 2994, 3005, 3017, 3018, 3019, 3071, 3151, 3152, 3153)

2959. Kil'chevskiĭ, N. A., Elements of tensor calculus and its applications to mechanics [Élementy tenzornogo ischisleniya i ego prilozheniya k mekhanike], Moscow, Gosud. Izdat. Tekh.-Teor. Lit., 1954, 167 pp. 5.15 rubles.

This diminutive booklet somehow contrives to cover more material than other books twice its size. For instance, it includes the representation of the motion of a system of rigid bodies as the motion of a particle in Riemannian space in nonholonomic constraints, and the invariant form of the equations of motion of

an elastic continuum. Whether this feat has been accomplished at the expense of clarity can be judged only by a reader not familiar with the subject. A sampling of the book did not reveal any obscure or loose statements. The brevity is partly achieved by omitting problems, exemplifications, and informal remarks aimed at giving mental comfort to the reader.

A. W. Wundheiler, USA

2960. Landau, L. D., and Lifshitz, E. M., The mechanics of continuous media [Mekhanika sploshnikh sred], 2nd ed., Moscow, Gosud. Izdat. Tekh.-Teor. Lit., 1953, 788 pp. 15.35 rubles.

Book treats the theory of motion of fluids and gases (hydrodynamics) and solid material (elasticity). The chapters on hydrodynamics are: (1) Ideal fluids; (2) Viscous fluids; (3) Turbulence; (4) Boundary layer; (5) Heat conduction; (6) Diffusion; (7) Surface phenomena; (8) Sound; (9) Shock waves; (10) One-dimensional gas flow; (11) Surfaces of discontinuity; (12) Plane gas flow; (13) Flow about a finite body; (14) Combustion; (15) Relativistic hydrodynamics; (16) Superfluidity; in all, 628 pages. Elasticity is confined to infinitesimal strain and comprises: (1) Basic equations; (2) Equilibrium of rods and plates; (3) Elastic waves; (4) Heat conduction; in all, 156 pages.

To cover such a vast field the treatment has to be concise. Nevertheless, the exposition is a model of clarity. Approximate and empirical methods are not treated and, to the authors' credit, they never seem to lose sight of the physical background. The book is clearly intended for physicists, but, in spite of the number of worked problems, it is difficult to see to what class of worker the book will appeal. In any one division there is too little for the specialist, while the whole could prove indigestible to the tyro. As giving an over-all picture, it is a magnificent effort.

L. M. Milne-Thomson, England

2961. Pars, L. A., Variation principles in dynamics, *Quart. J. Mech. appl. Math.* **7**, part 3, 338–351, Sept. 1954.

Author discusses the extension of Hamilton's principle to nonholonomic systems, a step whose validity has been questioned by R. S. Capon [AMR 6, Rev. 2142]. Contrary to the conclusions of Capon, author reaffirms the work of Holder and Voss (see article for references) and extends their results to nonholonomic, acatastic systems. "Acatastic" systems are those in which the coefficients of dt in the equations of constraint are not all identically zero.

Reviewer agrees with Pars' conclusions. A valid extension of the principle to nonholonomic systems may be made if the varied paths are constructed with displacements which satisfy the constraints. The varied path itself need not satisfy the equations of constraint. This is the usual procedure. Pars discusses a further extension that is possible if the correlated point, $q_i + \delta q_i$, on the varied path is occupied at the time $t + \delta t$. This procedure permits one to consider acatastic systems, and also leads to a generalized least-action principle.

P. H. Pitkanen, USA

2962. Graffi, D., Reciprocity in the dynamics of elastic bodies (in German), *Ing.-Arch.* **22**, 1, 45–46, 1954.

Author applies the Laplace transformation to the classical reciprocity theorem. Assuming that body forces and resulting displacements are functions of time, he arrives at a form of the theorem which is independent of unknown inertia forces. Several types of forces are considered, linear friction forces in particular. Reviewer feels that this is a simple example of the value of integral transformation methods in the study of time-varying systems.

W. M. Stone, USA

2963. Malïshev, A. P., Calculation of flywheel masses in machines (in Russian), *Akad. Nauk SSSR Trudi Sem. Teorii Mash. Mekh.* **13**, 52, 24–48, 1953.

2964. Blok, H., The dissipation of frictional heat, *Appl. sci. Res.* (*A*) **5**, 2/3, 151–181, 1955.

From the premise that the highest peaks of a solid body carry its load ("disperse" contact) and that the actual area of contact is the seat of frictional heat generation, author seeks to justify the contention of "a large local temperature rise" at the admittedly two-dimensional source with vast solid backing by considering the source as a "considerable constriction resistance."

It appears to reviewer as if the proposed analogy between frictional heating and a moving *constant* heat source breaks down when the result of variations of speed is reviewed.

Equilibrium temperatures in journal bearings are considered under simplifying conditions, such as constant film thickness and shear independence of viscosity over the full extent of the Stribeck curve.

R. Schnurmann, England

2965. Leone, W. C., and Ling, F. F., An apparatus for determining galling characteristics and measuring coefficients of kinetic friction, *Proc. Soc. exp. Stress Anal.* **11**, 1, 239–248, 1953.

A description is given of an apparatus, a variant of the "pin and disk" type, for studying the frictional and galling characteristics of metal combinations under well-controlled conditions of sliding speed and load. Repeatability of test results proved promising. Typical results are reported for various metal combinations.

H. Blok, Holland

2966. Duncan, W. J., A kinematic property of the articulated quadrilateral, *Quart. J. Mech. appl. Math.* **7**, part 2, 222–225, June 1954.

In the realm of mechanism, the four-bar linkage has an ancient and honorable history, but not much attention has ever been given to it as a freely moving kinematic chain of four members; i.e., before the fixing of one member constrains the chain to become a mechanism. If such an articulated quadrilateral is considered to move relative to the plane containing it, the five-member assembly so formed has ten centros which can be determined by applications of the Kennedy theorem. Author shows that there are two other significant points associated with this chain, one located in each diagonal of the figure. By means of the Pappus theorem from abstract geometry, he demonstrates that the "normals to the paths of two opposite vertexes meet on the diagonal through the other pair of vertexes." If the expression "normals to the paths" is replaced by the equivalent "instantaneous radii," the relationship of these points to the centros immediately becomes evident.

There is one well-known mechanism that contains an articulated quadrilateral in its assembly, the Peaucellier straight-line motion. The author applies his new relationship to this particular device, both the planar and the spherical forms, and shows that they are special cases of his original discussion.

Although not mentioned by author, if any moving link of his four-bar chain is assumed to have a centro arbitrarily chosen in the nonmoving plane, then a linear velocity may be given to one end of that link, and by means of components parallel to and

perpendicular to the other links in succession, it is possible to make the circuit of members and return to the first velocity again; the mere existence of the centro has produced sufficient constraint to give the resultant effect of a mechanism. If any other link of this chain is also assumed to have a centro arbitrarily chosen in the nonmoving plane, the additional constraint implied by this second centro will give the resultant effect of a structure; unless, of course, the original choices happen to fit the exact relationship of components that permit the circuit analysis just noted. It appears, therefore, that the articulated quadrilateral possesses only one degree of freedom. C. E. Pearce, USA

2967. Boes, G. F. G., Mechanical analysis of train movement (in Dutch), *Tech. Wet. Tijdschr.* **23**, 7, 165–171, July 1954.

After a few brief considerations about the motion diagram, the adhesion traction, and the drawing up of the general equation of the train movement, author offers a theoretical study of the various elements composing the rolling resistance and points to some of the most usual formulas of resistance. He proceeds with the various approximate and exact methods of computing the time and length of the runs. From author's summary

Servomechanisms, Governors, Gyroscopics

See also Revs. 2943, 3010, 3054, 3081, 3082, 3083, 3154, 3171, 3217)

©2968. Chestnut, H., and Mayer, R. W., Servomechanisms and regulating system design, Vol. II, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1955, xiii + 384 pp. $8.50.

The first volume of this work [AMR **5**, Rev. 2278] was published a few years ago and is one of the standard textbooks on basic servo theory. Vol. II, the subject of this review, is intended to meet the requirements of the advanced student or practicing engineer already acquainted with the basic theory of the subject. Topics covered are measurement techniques, assessment of input characteristics including noise (together with noise reduction), rating of power elements, collected data on networks, amplifier drift, a-c servomechanisms, and nonlinear systems (which rate three chapters).

Treatment is still elementary in the sense that even mildly difficult mathematics is avoided. In particular, the mathematical treatment of noise is largely by-passed, the authors being content to give little more than essential formulas and procedures. Elsewhere, as in the derivation of minimum inertia of gear trains, drastic and seldom justifiable simplifications are made, which make the results questionable, although the analysis might still help the critical reader who would probe the matter further by himself.

Techniques discussed for nonlinear systems are small perturbation analysis and the "describing function" technique developed by Kochenburger and others. Basic nonlinear theory is limited to a brief mention of phase-plane diagrams and limit cycles, and the grounds that its applicability to practical design is very limited, which is no doubt true as regards quantitative analysis but may be questionable as regards important qualitative findings. Perhaps also more could have been said on such subjects as special stabilization techniques for nonlinear systems such as "V mod V" feedback.

The real strength of the book lies in its preaching by example. Numerous illustrations of the subject matter are worked out, often in considerable detail, and various techniques are thus thoroughly drilled into the reader. A serious attempt is made to show at least some of the work involved in designing a practical servo, beyond the stage of basic response analysis. One might wish that further items on these lines had been included; for instance, the accuracy of servos is limited not only by the magnitude of error coefficients compatible with stability, but also by potentiometer resolution, minimum significant signal levels, etc., but one looks in vain for a discussion of such topics.

The style is often cumbersome or verbose, and on occasions the reader may have to turn to the examples to follow the authors' meaning. Some explanations, however, are very lucid, the analysis of a-c networks being a case in point.

R. Hadekel, England

2969. Nishihara, T., Sawaragi, Y., and Sawamura, T., On the method of solution by use of the vector locus for an automatic control circuit with many non-linear elements, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 349–352.

Authors define a transfer function of a nonlinear element in the following way: The element is fed by a harmonic input $\theta\ e^{i\omega t}$; the output will have a portion $\alpha\ e^{i\omega t}$ of the same frequency. This is called the "equivalent output." The ratio α/θ is called the "equivalent transfer function" of the nonlinear element. The rules of linear networks are used in order to find the equivalent transfer function of control circuits with nonlinear elements. Thus two nonlinear elements in series lead to the product of the individual equivalent transfer functions. Application is made to control circuits involving friction, clearance, and saturation. Theoretical and experimental results seem to agree.

Reviewer believes that the rules of combination of equivalent transfer functions are not correct in the most general sense. It can be easily checked that a series of two equal elements, each of which relates its output y to its input x by $y = x^3$, does not follow the law of multiplication of the individual transfer functions. Unfortunately, the paper is too short to give information about a limited class of control circuits for which the rules might be applicable. Incidentally, it seems that the authors mean the frequency response function rather than the transfer function.

H. F. Bueckner, USA

2970. Nomoto, A., Contribution to the root-locus analysis of the feedback control system, *Proc. 2nd Japan Nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 359–362.

The well-known relation $Y(s) = kG(s)/(1 + kG(s))$ for a feedback system with $kG(s)$ as the feedback transfer function, with k as static gain, and with $Y(s)$ as the over-all transfer function is taken as the basis for an expansion of $Y(s)/s$ in partial fractions. For this expansion the form $Y/s = \sum_{n=1}^{m} A_n/(s - s_n)$ with $G(s_n)$ real and negative is assumed. The root locus $s = f(m)$, defined by $1 + mG(s) = 0$ for real and positive values of m, is used to determine the coefficients in the form $A_n = d \log s/ d\log(-m)$ for $m = k$, $s = s_n$ by graphical differentiation. Application of the inverse Laplace transform to the expansion of Y/s gives information on the transient response of the feedback system. Some examples are discussed. H. F. Bueckner, USA

2971. Trant, J. P., Jr., Preliminary investigation of a stick shaker as a lift-margin indicator, *NACA TN* 3355, 19 pp., Feb. 1955.

Preliminary tests with simulator equipment were made to determine the ability of subjects to use frequency or amplitude of vibration of the pilot's control stick, or both, as an indicator for maintaining a desired lift margin below the stall. The results

showed that the desired lift margin could probably be maintained, provided the allowable variation from the desired angle of attack or lift coefficient produced either changes in amplitude of vibration of about 100% or changes in frequency of 40% or both.

From author's summary

2972. Hart, J. J., Stability of umbrella-type vertical waterwheel generators, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-148, 7 pp.

The mechanical stability of vertical umbrella waterwheel generators is analyzed under normal and abnormal conditions. Four typical generators of recent designs are used in this analysis in order to provide a practical understanding of the magnitude of the forces involved. The results indicate a large factor of safety maintaining generator stability. From author's summary

2973. Anonymous, Railroad air brake systems reveal fundamentals of pneumatic circuit design, *Proc. Engng.* **25,** 11, 134–137, Nov. 1954.

2974. Taylor, L. D., Hydraulic motors for automatic control, *Prod. Engng.* **25,** 11, 129–133, Nov. 1954.

2975. Magnus, K., Contributions to the dynamics of force-free gyroscopes with Cardan bearings (in German), *ZAMM* **35,** 1/2, 23–34, Jan./Feb. 1955.

If the motion of a force-free gyroscope with Cardan bearings contains a nutation, it is influenced by the inertia of the Cardan rings. If the rotor is symmetrical, this influence consists in a precession. In the case of an asymmetrical rotor, the conditions of stability are modified. Both effects depend on the slope of the rotor axis. The first of them is investigated by means of a perturbation method, the second one by means of Floquet's theorem.

H. Ziegler, Switzerland

Vibrations, Balancing

(See also Revs. 2944, 2952, 2971, 3020)

2976. Shteinberg, T. S., Periodic solutions of the differential equation of nonlinear vibrations when "dry" and "viscous" friction forces are present (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 4, 13–22, Apr. 1954.

A method of qualitative analysis of the differential equation of nonlinear vibrations is given. The problem is solved by the construction of annular regions in the phase diagram, containing periodic solutions of the investigated equation. For the construction of these regions, the known periodic solutions of a simplified, linear equation with constant coefficients are used. The application of the method is illustrated by two examples.

D. Radenković, Yugoslavia

2977. Hohlov, R. V., On the theory of entrainment for small amplitude of the external force (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **97, 411–414, 1954.**

This is basically a study of entrainment for

$$\ddot{x} - 2\delta_0(x)\dot{x} + \omega_0^2 x = E\omega_0^2 \cos pt$$

by the approximation methods of Krylov and Bogolyubov ["Introduction to nonlinear mechanics," Princeton, 1943]. A rather complete discussion is given and the boundary of the region of entrainment is assigned as determined by $|p - \omega_0| = E\omega_0/2A_0$, where A_0 is the amplitude of the free self-oscillations.

S. Lefschetz, USA

2978. Sung, T. Y., Vibrations in semi-infinite solids due to periodic loading, *Harvard Univ. Soil Mech. Ser.* no. 48, 1955. (Reprint: ASTM Spec. techn. Publ. no. 156, 1953, 35–68.)

Paper considers response of mass m_0 with base radius r_0 resting on an elastic isotropic semi-infinite solid due to a vertical periodic force. It extends the work of E. Reissner [*Ing. Arch.* **7,** 381–396, 1936]. Author gives analysis for following pressure distributions between mass and solid: (a) uniform (Reissner assumption); (b) parabolic; (c) that produced by a rigid base, assuming equivalent static and dynamic stress distribution.

Results are given for each assumption and various values of Poisson's ratio and $m_0/\rho r_0^3$(ρ density of solid). Relation of maximum amplitude and resonant frequency to these parameters also is given.

Experimental values obtained from mechanical vibrators on soil are used with theory to predict constants of soil and correct pressure distribution. Reviewer believes distribution (c) to be the best approximation and that nonlinearity of experimental media affects results. R. N. Arnold, Scotland

2979. Chubachi, T., Vibration of string and beam with time-dependent lengths, *Proc. 1st Japan nat. Congr. appl. Mech.,* 1951; Nat. Committee for Theor. appl. Mech., May 1952, 605–610.

Paper gives solution for lateral vibrations of strings of varying length with constant velocity, and solution for lateral vibration of cantilever beam of varying length with velocity inversely proportional to its length. Independent modes of oscillation are found which correspond one to one with the normal modes in the case of constant length. The amplitudes of normal modes are constant for a string and are approximately proportional to the square root of length for a cantilever. P. G. Jones, USA

2980. Chubachi, T., and Nagai, K.-i., Lateral vibration of axially moving wire or belt form materials (in Japanese), *Trans. Japan Soc. mech. Engrs.* **21,** 103, 193–198, 1955.

A theoretical analysis is presented for the lateral vibration of wire or belt form materials in case of axial movement through two supporting points under the condition of fixed slope at these points. The report contains the theory of critical speeds, the characteristic equations for the materials with flexural rigidity, and the analysis of frequency curves for some special conditions.

From authors' summary

2981. DiPrima, R. C., and Handelman, G. H., Vibrations of twisted beams, *Quart. appl. Math.* **12,** 3, 241–259, Oct. 1954.

The geometry of a twisted beam may be represented by a vector triad defining the twist per unit length of the center line. The equations of static equilibrium, using this representation and derived by W. Prager, are generalized into a system including dynamic effects.

This representation is compact and elegant and takes care of both transverse and torsional vibrations. Depending on the coincidence between centroid and center of twist, transverse and torsional vibrations are coupled or not.

The eigenvalues of corresponding problem are obtained from a minimum principle of the Rayleigh type. Equations are fur-

thermore extended to include effect of rotation on a twisted beam.

Authors illustrate their method by a numerical example of a uniform nonrotating cantilever beam with a constant twist. Their results agree with experimental data.

F. I. Niordson, Sweden

2982. Kruszewski, E. T., and Kordes, E. E., Torsional vibrations of hollow thin-walled cylindrical beams, *NACA TN* 3206, 33 pp., Aug. 1954.

The differential equations for the analysis of torsional vibrations of hollow thin-walled cylindrical beams are obtained. General solutions for the modes and frequencies of cantilever and free-free cylindrical beams of doubly symmetrical section with uniform thickness are derived. The effect of longitudinal inertia and bending stress due to torsion on torsional vibration is shown. Numerical results of the solution of cylinders of rectangular section are compared to those obtained from an analysis of an equivalent four-flange box beam. T. H. Lin, USA

2983. Yamamoto, T., On the vibrations of a shaft supported by bearings having radial clearances (in Japanese), *Trans. Japan Soc. mech. Engrs.* **21**, 103, 186–192, 1955.

In this paper, the stability criteria of the forced vibrations of a shaft, the response curves, and the jump phenomena are discussed.

From author's summary

2984. Kiuchi, A., On the lateral vibration of a shaft with generalized terminal conditions (in Japanese), *Trans. Japan Soc. mech. Engrs.* **21**, 103, 199–205, 1955.

2985. Melvin, M. A., Centroidally bordered bodies and the balancing *L*, *Amer. J. Phys.* **23**, 3, 131–135, Mar. 1955.

The preparation of bodies which have the property that the mass center lies on the periphery is considered. It is demonstrated that, starting from a large variety of shapes, including all those here called "medially convex," it is always possible to prepare a centroidally bordered shape by cutting a simple triangular notch out of the basic shape. Incidentally it is proved that every area which is medially convex with respect to a base b is at least 8/3 times as great as the area of the centroid triangle constructed on the base b. The method of triangular notching is applied in detail to several familiar shapes, including the general trapezoid and circular segment. The preparation of a centroidally bordered shape from a basic shape which includes a straight angle in its boundary is also considered. The solution by quadrilateral notching is indicated but not carried through in detail. The simple solution for the special case of the balancing L is written down and illustrated photographically.

From author's summary

2986. Stern, M., Matrix method of coupling shear flexibility and rotatory inertia in bending vibration, *J. aero. Sci.* **22**, 4, 276–278, Apr. 1955.

Note in Readers' Forum.

2987. Larri, G., Automatic balancing of rotating masses, *Prod. Engng.* **25**, 7, 175–178, July 1954.

Paper describes the Duncan fluid balancer (patent applied for), which is an application of the following principle: When a body, with arbitrary density distribution and a mean density smaller than that of a fluid contained in a rotating vessel, is kept immersed by means of an external force, the body automatically takes a position so that the center of gravity of the system comprising the total fluid and the body coincides with the axis of rotation. Author gives a clear picture of the possibilities of the balancer and discusses the application in a spin drying machine. He says there are also applications in several rotating types of "hydroextrators." M. Kuipers, Holland

2988. Meldahl, A., Balancing of elastic rotors (in German), *ZAMM* **34**, 8/9, 317–318, Aug./Sept. 1954.

2989. Slibar, A., and Desoyer, K., Obtaining optimum effect in pendulum vibration annihilation (in German), *Ing.-Arch.* 22, 1, 36–44, 1954.

Treating simply connected pendulum solids as a mathematical pendulum may be only a rough approximation. Authors take physical pendulum as basis of examination. Then, variables are: mass of pendulum, length, distance of fixing point of pendulum from center of waves, and radius of inertia of pendulum related to its center of gravity. Possibility of best combination of these parameters gives essentially greater freedom of construction in order to obtain least vibration of angular velocity of the main mass. The possible means of practical calculation of parameters of a simply connected damping pendulum are combined. Calculation may be applied especially to radial engines.

W. Kochanowsky, Germany

2990. Billman, G. H., Vibration and shock control: a design tool, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-202, 10 pp.

Paper treats the subject of vibration and shock control as related to product design. It is shown how, through application of engineered suspension systems, material savings, improved performance, and longer product life are realized. Attention is given to the variety of control systems and products, the design of which represents marked engineering achievements.

From author's summary

Wave Motion in Solids, Impact

(See also Revs. 2960, 3086)

2991. de Klerk, J., and Musgrave, M. J. P., Internal conical refraction of transverse elastic waves in a cubic crystal, *Proc. phys. Soc. Lond.* (*B*) **68**, 422B, part 3, 81–88, Feb. 1955.

Paper begins with a theoretical discussion of the propagation of elastic waves in a cubic crystal; this discussion is based on a more general analysis due to one of the authors [Musgrave: *Proc. roy. Soc.* (*A*) **226**, p. 339, 1954] and its aim is to find whether the phenomenon of internal conical refraction, familiar in optics, can occur with elastic waves. The treatment is confined to transverse waves of normal (1,1,1) and, using a recently developed geometrical method for deriving the elastic wave surface, it is shown that the phenomenon exists and the value of the semi-angle Δ_c of the cone of refraction is calculated from the values of the elastic constants for a number of metals.

Experiments were carried out using a single crystal of nickel; pulsed quartz transducers were used to generate and detect the elastic waves. The results confirm the theoretical calculations, the observed and calculated values of Δ_c being 21° and 25°, re-

spectively; the discrepancy is shown to be due to the spread of the transmitted beam.

The paper is an important contribution to the study of stress waves in aeolotropic media and it gives the first demonstration of the existence of internal conical refraction.

R. M. Davies, Wales

2992. **Anderson, R. A., Wave groups in the flexural motion of beams predicted by the Timoshenko theory,** *J. appl. Mech.* **21,** 4, 388–394, Dec. 1954.

The response of an infinite beam to a transverse-force impulse and to a bending-moment impulse is studied on the basis of the Timoshenko theory. A model approach is used, considering first a finite beam and letting, subsequently, its length become infinite.

G. Herrmann, USA

2993. **Crede, C. E., The effect of pulse shape on simple systems under impulsive loading,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-203, 9 pp.

Paper proposes modified parameters for presenting "shock spectra" for elastic systems acted upon by acceleration pulses. It is shown that the ratio of maximum response acceleration to maximum acceleration of the pulse is a function of the pulse shape. By introducing velocity change (impulse or change in momentum) in place of maximum acceleration of the pulse, the influence of pulse shape on the spectrum is materially reduced. The significance of the spectrum for lightly damped systems is considered, where failure may result from fatigue after many cycles of stress reversal induced by a single pulse.

From author's summary

2994. **Raher, W., The d'Alembert principle in the motor symbolism and its application to impact problems** (in German), *ZAMM* **34,** 8/9, 323–324, Aug./Sept. 1954.

By the motor calculus [v. Mises, *ZAMM* **4,** 2, 155–181, 1924], a force together with a coaxial couple and other analogous objects (screws) can be represented by a single symbol, the motor. It is completely determined by two vectors, the first of which is the force vector and the second the resultant moment about a given point of the force and the couple. The d'Alembert principle applied to the motion of a system of rigid bodies can be, therefore, formulated in a single motor equation, which, in the case of impact, yields an equation for the momentum motor before and after the impact. The last quantity is further determined by the system of impulse motors and by the motors of virtual velocities of bodies. The general equation is applied to the impact of an impulse on a system of two rigid bodies connected by a joint and to an anholonomic system of two wheels rolling over a plane when a sudden impulse is imparted to the axis.

The numeration of both figures in the paper is reversed.

A. Kuhelj, Yugoslavia

Elasticity Theory

(See also Revs. 2962, 2981, 3008, 3009, 3025, 3041, 3055, 3164)

Ⓑ2995. **Swainger, K., Analysis of deformation. Vol. 2. Experiment and applied theory,** London, Chapman & Hall, Ltd., 1954, xxxvi + 365 pp. 70s.

This book is the second of a three-volume work. Vol. 1 presented the formulation of an original theory of deformation (finite), which author described by one set of mathematically linear equations. Present volume is meant to deal with the applications of this theory.

First two chapters (41 pages) contain experimental and theoretical considerations for "one-stress" (simple tensile or compressive stress). Chaps. 3 and 4 (87 pp.) treat homogeneous two-stress, and curvilinear two-stress, where the latter is a "two-dimensional two-stress distributed over a curvilinear surface" (thin-walled circular tube, for example). The general problem of plane stress is given in chap. 5 (31 pp.) and some experiments conducted by the author on thin plates in chap. 6 (6 pages). Theoretical examples in plane-stress receive attention in chap. 7 (42 pp.), among which solutions are given for normal and shear loading on the cylindrical faces of an elastic annulus, tension at infinity in an elastic sheet with a circular hole, etc. Chaps. 8 and 9 (12 pp.) deal with equations and analyses for a general type of loading ("three-stress"). A detailed treatment of the deformation of rubber is given in chap. 10 (25 pp.), where the theories of Seth, Murnaghan, Mooney, Kuhn, Treloar, and Rivlin all receive critical comment. Last two chapters (39 pp.) present various treatments of the torsion problem. Four Appendixes (41 pp.) are entitled "Vector analysis," "Complex variable," "Finite differences," and "Fourier series."

Reviewer notes that author's approach to finite deformations is highly original and completely devoid of any bias to the work of previous investigators. This attitude is to be commended, but criticism of previous work from the Navier, Cauchy, Saint Venant era to the present day seems unjustly harsh and, in places, in poor taste. The relative merits of author's theory and analyses may only be judged through time, when the various workers in the field give critical examination to the many new facets introduced in these volumes. Quoting from author's preface: "Because the theory conflicted with the generally accepted old theories, it proved impossible to have published a full account in the scientific journals, so the present treatise was undertaken." A serious inference is contained in this quotation and reviewer hopes that author's "Analysis of deformation" will receive fair yet firm evaluation. As in vol. 1, vector-dyadic notation is used throughout. Symbolism becomes complicated and the book most difficult to study.

M. C. Steele, USA

Ⓑ2996. **Green, A. E., and Zerna, W., Theoretical elasticity,** New York, London, Oxford Univ. Press, 1954, xiii + 442 pp. $8.

This remarkably elegant and authoritative volume on elasticity is not intended to be an exhaustive treatise but, as stated in the preface, is confined to three aspects of the theory of elasticity which have received considerable attention in recent years. In a few instances, the emphasis placed on mathematical sophistication surpasses the care given to the physical character of the topics, and, since tensor and vector calculus are employed extensively throughout the book, some readers may find it diffiult to follow. The contents of the book, largely a reflection of the authors' interests, are arranged in 14 chapters, and chap. 1 (52 pages) contains a summary of tensor analysis (in three-dimensional Euclidean space) and some results from functions of a complex variable and Fourier integrals.

Nearly one quarter of the book (chaps. 2–4) is devoted to finite elastic deformations, giving particular attention to isotropic bodies. Following the presentation in chap. 2 of a general theory of elasticity for finite displacements, solutions of specific problems, based primarily on the work of R. S. Rivlin, are discussed in chap. 3. Chap. 4 is concerned with the theory of small deformations superposed on finite deformation due to A. E. Green, R. T. Shield, and R. S. Rivlin.

The second aspect of elasticity treated (chaps. 5–9), occupying

more than one half of the book, is concerned with the linear theory and its application. Following a rather brief account of the general infinitesimal theory (obtained as a limiting case of the general theory of chap. 2), the elastic coefficients for various anisotropy (aeolotropy) are discussed in chap. 5, and solutions of the fundamental equations in terms of potential functions for isotropic (the three-function approach of Boussinesq-Papkovich-Neuber) and hexagonally anisotropic bodies are given and applied to a few problems. Chaps. 6 to 9 are devoted to the theories of plane strain and generalized plane stress, as well as plate theory, with application to a large class of isotropic and anisotropic bodies; also included is E. Reissner's theory for bending of isotropic plates. The contents of these four chapters are treated by the use of complex variable techniques which were first developed by M. Kolossoff and N. I. Muskhelishvili and extended further by S. G. Lechnitsky, A. C. Stevenson, and A. E. Green.

The last five chapters (62 pages) of the book embrace the linear theory of thin isotropic shells. In chap. 10 a consistent general bending theory of shells is derived from the linear equations of elasticity; although reference is made to more recent contributions due to E. Reissner and to the authors, the results obtained are in accordance with the classical theory of shells. Through appropriate and systematic approximations, a theory for shallow shells is presented in the next chapter and applied to the problem of spherical cap. Chaps. 12–14 deal, respectively, with the general membrane theory of shells, the theory of cylindrical shells, and the membrane theory of shells of revolution with a discussion of the "edge effect."

It appears that the authors have given considerable thought to the scope limitation of this well-organized and indispensable book; nevertheless, it seems to this reviewer that the linear theory of elasticity contained in chap. 5 has not received the attention it deserves, and likewise, the inclusion of more recent developments in the theory of shells would have been of considerable interest. Relatively speaking, only a few references are cited and, to some readers, this might be somewhat disconcerting. In general, however, the references have been carefully selected in that they contain other relevant references and, in some cases [such as Truesdell's memoir, *J. rat. Mech. Analysis* **1**, 125–300, 1952], a comprehensive up-to-date bibliography of the subject. One recent book, however, is not mentioned or referred to by the authors: Westergaard's monograph [AMR **7**, Rev. 1033], where important three-dimensional topics in the linear theory (not covered in this book) may be found.

P. M. Naghdi, USA

2997. Slobodyanskiĭ, M. G., General formulas for solutions of elasticity equations for simply and multiply connected fields, expressed in harmonic functions (in Russian), *Prikl. Mat. Mekh.* **18**, 1, 55–74, Jan./Feb. 1954.

The use of harmonic and biharmonic functions of Lamé, Boussinesq, Trefftz, Galerkin, Papkovich, etc., is convenient only in solving certain particular problems of the theory of elasticity. Further studies of the Papkovich functions were undertaken by G. D. Grodskiĭ [*Izv. Akad. Nauk Otd. Mat. i Estestv. Nauk*, no. 4, 1935]. The first part of the paper contains the derivation and proof of generality of two forms of general solutions of the theory of elasticity for simply and multiply connected regions, one being the form of Papkovich-Grodskiĭ, the other being due to the present author. These two forms are compared in the second part, where finite and infinite regions are considered and three harmonic functions are used.

G. Herrmann, USA

2998. Sherman, D. I., Connection between the principal problem in the theory of elasticity and a particular case of Poincáre's theorem (in Russian), *Prikl. Mat. Mekh.* **17**, 6, 685–692, Nov./Dec. 1953.

Author shows how the fundamental problem of plane theory of elasticity may be reduced to Fredholm's equations. This is accomplished by resolving the displacement vector in a manner different from the usual one. Author believes that his scheme may be extended to other cases.

G. Herrmann, USA

2999. Hearmon, R. F. S., "Third-order" elastic coefficients, *Acta Cryst.* **6**, 331–340, 1953.

The author's object is to determine the forms of the cubic terms in the strain energy of a perfectly elastic body appropriate to the various classes of crystals. He uses explicit calculation and obtains results in agreement with those of Fumi [*Phys. Rev.* (2) **83**, 1274–1275, 1951]. For the isotropic case there are at most three independent coefficients, as has long been known. [The author in discussing an erroneous reduction of the three to two is apparently unaware of the general method which enables one to determine at once the form of the strain and energy in the isotropic case; e.g., the reviewer, §8 and §43 of *J. rat. Mech. Analysis* **1**, 125–300, 1952; **2**, 595–616, 1953. Since the author's paper appeared, this classical method has been generalized to the anisotropic case in §6–§7 of Ericksen and Rivlin (see following review). While Ericksen and Rivlin work out the details only for the case of transverse isotropy, their method is entirely general, and not only does it avoid the necessity for lengthy calculation but also it applies to strain energies of any form.]

C. Truesdell, USA

3000. Ericksen, J. L., and Rivlin, R. S., Large elastic deformations of homogeneous anisotropic materials, *J. rat. Mech. Analysis* **3**, 3, 281–301, May 1954.

The tensor character of stress and large strain, suitably defined, and the scalar character of the strain-energy function prescribe the most general forms elastic stress-strain relations may take. These forms are further restricted when the material possesses any elastic symmetry, or when it has intrinsic constraints, as a block of rubber reinforced by a system of inextensible cords. Paper gives a general tensorial formulation of these restricted relations, obtaining stress by differentiation of strain energy subject to auxiliary conditions expressing the symmetries or constraints. Detailed application is made to rotational symmetry and to "transverse isotropy" (symmetry also with respect to reflection in any plane containing the axis of the rotational symmetry). For incompressible materials of this kind, a simple finite deformation in cylindrical coordinates with five disposable constants is evaluated as to stress, following Rivlin's plan of working with the strain-energy function itself, not particularized further.

By special choices of the five constants, the results are found to express: (1) Simultaneous extension and torsion of a circular cylinder; (2) simultaneous inflation and elongation of a hollow cylinder; (3) a generalization, as to finite deformation and type of material, of the Volterra dislocation of a cylinder by closing the angular gap between two axial planes; (4) cylindrical flexure of a block; and (5) a rotating cylinder.

The paper provides significant additions to both general theory and special problems.

J. N. Goodier, USA

3001. Kaczkowski, Z., Calculation of anisotropic plates according to the method of superposition of wave surfaces (in German), *Bull. Acad. Polonaise Sci.* **2**, 2, 79–84, 1954.

A method is presented for calculating the deflections of anisotropic plates, resting upon an elastic underground, loaded in and perpendicular to their plane. The load perpendicular to the plane of the plate is considered as a superposition of two or more

periodic functions of one coordinate. Provided the loads and the elastic properties of the plate satisfy certain relations, the linear fourth-order partial differential equation from the small deflection theory for plates is reduced to a linear ordinary fourth-order differential equation and the total deflections are found as a superposition of two or more periodic deflection functions, each depending only on one coordinate.

As an example author gives the case of a rectangular plate with simply supported edges under a pyramidal load and the case of a simply supported equilateral triangular plate bent by moments uniformly distributed along the boundary.

More general applications of the method are suggested in the paper, such as the determination of buckling loads and of natural frequencies and vibration modes. J. F. Besseling, Holland

3002. **Sadowsky, M. A., Thermal shock on a circular surface of exposure of an elastic half space,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-44, 6 pp.

A mathematical method is given for determining the displacement and stress, in the elastic half-space, arising from the application, to a portion of the surface, of heat which does not penetrate into the interior of the body. The case of the uniformly heated circular area is treated in detail. (Reference may be made to AMR **4**, Rev. 3494, for a method applicable when the heat penetrates into the interior.) R. D. Mindlin, USA

3003. **Coffin, L. F., Jr., A study of the effects of cyclic thermal stresses on a ductile metal,** *Trans. ASME* **76**, 6, 931–950, Aug. 1954.

See AMR **7**, Rev. 2481.

3004. **Fritz, R. J., Evaluation of transient temperatures and stresses,** *Trans. ASME* **76**, 6, 913–921, Aug. 1954.

Author first describes the formulation of boundary-value problem for an arbitrary surface temperature transient (which can be approximated by several linear functions) in semi-infinite media. If a slab of finite thickness is exposed to thermal transient at one surface with the opposite surface insulated, then the temperature distribution inside the slab may be written directly in terms of the known solution for the semi-infinite media. This is accomplished by superimposing the effect of thermal shock waves reflected from free-insulated boundaries. Evaluation of stresses set up in thin cylindrical shells by transient temperature is discussed, and the maximum stresses are tabulated for several commonly encountered vessels. Material behavior under thermal effect is also described briefly.

Reviewer believes the paper is a good refresher to designers of piping and pressure vessels operated at elevated temperature.

D. H. Cheng, USA

3005. **Fazekas, G. A. G., Temperature gradients and heat stresses in brake drums,** *SAE Trans.* **61**, 279–308, 1953.

This paper shows that high brake temperature alone is not the cause of failure, but rather a combination of factors of which high stress and high temperature are the principal ones.

Some stresses due to temperature gradient reach well into the plastic state, even in comparatively cool brake drums, causing crazing of the track, heavy scoring, heat checks, outright fracture, and other phenomena.

A detailed mathematical analysis as well as mechanical design is included to provide a rational basis for appraising the suitability of drum materials. Some of the author's brake-drum designs are included for examples. H. F. Marco, USA

3006. **Coffin, L. F., Jr., and Wesley, R. P., Apparatus for study of effects of cyclic thermal stresses on ductile metals,** *Trans. ASME* **76**, 6, 923–930, Aug. 1954.

See AMR **7**, Rev. 2482.

Experimental Stress Analysis

(See also Revs. 3046, 3081, 3082)

3007. **Mönch, E., The dispersion of double refraction as a measure of plasticity in photoelastic investigations** (in German), *Forsch. Geb. Ing.-Wes.* (*B*) **21**, 1, 20–25, 1955.

The application of the common methods of two-dimensional photoelasticity to the problems of plasticity can only give incomplete results because of the complex character of these phenomena. The author shows in his paper that we can get further indications when the stress patterns of monochromatic light of two different wave lengths are successively determined. These indications are all the more exact if there is little variation in the velocity of deformation at every point of the body. The author applies this method to a bar under tension which is formed of two coaxial prismatical parts of different thickness joined by a crossing.

H. Favre, Switzerland

3008. **Work, C. E., and Dolan, T. J., Applications of experimental stress analysis to torsion research,** *Proc. Soc. exp. Stress Anal.* **12**, 1, 79–90, 1954.

A system of electrical, optical, and mechanical instruments developed for torsion measurements on metals at varying strain rates and temperatures is described. The system described is capable of continuously recording twisting moment, angle of twist, and elapsed time at strain rates ranging from 0.0001 to 12.5 in. per in. per sec and at temperatures from room temperature up to 1200 F.

The apparatus described is relatively complex and, hence, its use would seem possible for large-scale programs only.

W. H. Duckworth, USA

3009. **Olszak, W., Generalization of the elastic membrane analogy to problems of anisotropic systems** (in Polish, with French summary), *Arch. Mech. stos.* **5**, 89–106, 1953.

The Prandtl analogy of the uniformly stressed membrane subjected to a normal load with an isotropic prismatic bar subjected to torsion is described in detail by R. D. Mindlin and M. G. Salvadori [Hetényi (ed.), "Handbook of experimental stress analysis," Wiley, New York, 1950, pp. 700–827]. The analogy consists in the fact that the partial differential equation for the displacement of the membrane is identical with the stress function differential equation of an isotropic bar, if the displacements of the membrane are small. The differential equations of anisotropic bars differ from that of a membrane, but author shows that, by a suitable transformation of the coordinates, they can be reduced to the isotropic case, and the membrane analogy may also be conveniently applied. By using the membrane analogy, author demonstrates that the cross sections of a circular anisotropic bar subjected to torsion must be warped, finds the conditions for which the cross sections of an elliptic anisotropic bar will remain plain, and discusses other seemingly difficult anisotropic bars which yield easy solutions by membrane analogy.

T. Leser, USA

3010. **Gerard, G., and Papirno, Note on photoelastic study of a swept-wing model,** *J. aero. Sci.* **21**, 12, 846–847, Dec. 1954.

Note in Readers' Forum.

3011. Loh, Y. C., Internal stress gauges for cementitious materials, *Proc. Soc. exp. Stress Anal.* **11,** 2, 13–28, 1954.

Paper presents a discussion of (1) the factors to be considered in the design of internal gages, (2) the construction of an internal stress gage, and (3) the test results of embedded stress gages.

For accurate internal measurement in concrete, the embedded gage and the concrete must have identical physical properties. But for a heterogeneous and semiplastic material like concrete, perfect matching of physical properties cannot be realized. The error introduced due to imperfect matching, and the design methods used to reduce the errors are discussed.

An internal stress gage designed for both static and dynamic measurements is described. The gage is 1/2-in. diam and 1-1/4 in. long, and its working range is from 1000 lb/sq in. in tension to 9000 lb/sq in. in compression.

The test results of embedded gages under compressive, tensile lateral, sustained, and dynamic loads are presented.

From author's summary

3012. Post, D., Photoelastic stress analysis for an edge crack in a tensile field, *Proc. Soc. exp. Stress Anal.* **12,** 1, 99–116, 1954.

3013. Frocht, M. M., and Pih, H., A new cementable material for two- and three-dimensional photoelastic research, *Proc. Soc. exp. Stress Anal.* **12,** 1, 55–64, 1954.

Paper presents the results of an investigation of the mechanical and optical properties of a new photoelastic material marketed under the trade name of Castolite.

From authors' summary

Rods, Beams, Cables, Machine Elements

(See also Revs. 2979, 2981, 2984, 2987, 2988, 2992, 3048, 3070)

3014. Semonian, J. W., and Anderson, R. A., An analysis of the stability and ultimate bending strength of multiweb beams with formed-channel webs, *NACA TN* 3232, 28 pp., Aug. 1954.

Design curves and procedures are presented for calculating the stresses for instability and failure of multiweb beams with formed-channel webs. The ultimate bending strength of this type of construction is shown to depend upon the deflectional stiffness of the web attachment flanges. A simple criterion is also given for predicting whether a multiweb beam with a given attachment-flange design will be susceptible to a wrinkling instability or will buckle as if the webs were integrally joined to the cover skins.

The criteria for predicting buckling and failure stresses are compared with experimental data. These criteria are sensitive to the offset, pitch, and diameter of the rivets used on the web attachment flanges, and the riveting specification is, therefore, emphasized as an important design consideration.

From authors' summary by T. H. H. Pian, USA

3015. Eimer, Cz., On designing of bent-up cables in prestressed beams (in Polish), *Inżyn. Budown.* **11,** 5, 134–138, May 1954.

Author is concerned with the problem of determining distances between points of anchorage along the top flange of a prestressed beam in cases where, for reasons of design and/or steel economy, only some cables are anchored at the end faces of the beam, the remainder being anchored at intervals along the top flange of the beam.

Assuming the limiting case of an infinite number of cables, an integral expression for the vertical shear force V induced by the bent-up cables in any cross section is obtained, from which a general relation between that force and the distance between cables is deduced. Specific solutions are given for the case when $V =$ const and when $dV/dx =$ const. It is claimed that the error in most practical cases would not exceed 10%, though it is stressed that the method is particularly suitable for beams with a large number of cables.

The value of V is obtained from the condition of minimum shear force and all quantities other than the sought distance between bent-up cables are taken as given, though some characteristics, e.g., the position of the first bent-up cable, may have to be adjusted to satisfy conditions of maximum working stresses.

An example of calculations is given.

Imperial Chemical Industries Ltd.
(Metals Division), England

3016. Kasper, L., Cams—design and layout, New York, Chemical Publishing Co., Inc., 1954, 101 pp. $3.50.

Brief clear exposition of design of slow-speed cams of all types by graphical layouts. No consideration is given to velocities or accelerations, nor dynamic problems of high-speed cam mechanisms.

E. M'Ewen, England

3017. Peres, N. J. C., Geometry of involute helicoidal hob and gear teeth, *Austral. J. appl. Sci.* **5,** 4, 309–329, Dec. 1954.

The geometry of the involute helicoid is treated quite generally in terms of familiar gear parameters. It is shown how the radius of curvature of the axial section becomes very large when the pitch-helix angle is large.

The coordinates of any point on the curve of intersection of a plane normal to the pitch helix and the surface are derived.

The equations for various other sections of the surface, often given in texts without adequate proof, follow immediately from the general treatment.

From author's summary by J. Boehm, USA

3018. Acker, D. D., and Maschmeyer, A. H., Backlash considerations in gear train design, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-111, 11 pp.

Paper formulates a method for determining backlash in precision gear trains. The contributions of idler gears, of electromechanical components (motors, synchros, potentiometers, etc.), of adapters, and of temperature to backlash in a mechanism are discussed. A method for calculating backlash when a gear train contains a differential is included. Finally, in the summation, suggestions are offered to aid the engineer in designing a gear train to meet stipulated specifications.

From authors' summary

3019. Kudryavtsev, V. N., Determination of the efficiency of planetary transmission gears taking into account the loss in the gears and bearings (in Russian), *Akad. Nauk SSSR Trudi Sem. Teorii Mash. Mekh.* **13,** 52, 5–23, 1953.

3020. Tokue, T., On the prevention of fatigue failures in valve springs of internal-combustion engines, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 179–186.

As a result of static and dynamic tests conducted on plain valve springs as well as on lead-coated and on copper-coated

springs, author reports that lead coating practically eliminates stress magnification due to surges and resonances, and copper coatings produce substantial reduction in such stresses.

A. Yorgiadis, USA

Plates, Disks, Shells, Membranes

(See also Revs. 2982, 3001, 3036, 3037, 3040, 3051, 3065, 3087, 3159, 3236)

3021. **Duncan, J. P., The structural efficiency of tube-plates for heat exchanger,** *Proc. Instn. mech. Engrs.*, 3–16, May 1955.

Work is primarily a report of experimental data on deflections and strains in a circular plate that is simply supported at the periphery and that contains a large number of staggered circular perforations in an equilateral triangular pattern. An annular region adjacent to the boundary was not perforated. Perforations were arranged first in quadrants separated by unperforated diametral strips, then in semicircles separated by an unperforated diametral strip, and, finally, in a complete circle, so that four-pass, two-pass, and single-pass tube plates of heat exchangers were simulated. Three types of loading were studied—point loads at the center, line distributions of load on a circle concentric with the boundary, and uniform distributions of lateral pressure.

Horvay and Malkin have derived effective values of Young's modulus and Poisson's ratio, so that perforated plates may be analyzed as equivalent solid plates. Author uses this theory to analyze single-pass plate with unperforated annular region adjacent to boundary. He finds that the results tend to confirm Horvay's theory.

H. L. Langhaar, USA

3022. **Crossland, B., and Bones, J. A., The ultimate strength of thick-walled cylinders subjected to internal pressure. I—Apparatus for producing very high pressures,** *Engineering* 179, 4643, 80–83, Jan. 1955.

Authors briefly review existing methods for theoretical or empirical solution of the problem. Detailed descriptions of test specimens and high pressure apparatus are given.

Å. Isaksson, Sweden

3023. **Crossland, B., and Bones, J. A., The ultimate strength of thick-walled cylinders subjected to internal pressure. II—Test results and their relation to ultimate-strength equations,** *Engineering* 179, 4644, 114–117, Jan. 1955.

Thirteen mild-steel specimens are tested, their initial ratio of external to internal diameter varying between 1.331 and 3.717. Experimental ultimate strengths are compared with those predicted by formulas given in part I (see preceding review). Authors report good agreement for two methods, the mean diameter formula and a theory due to Manning. They prefer the latter as being the only one logically based.

Å. Isaksson, Sweden

3024. **Stafford, P. M., Rational thickness design for pressure vessels,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-84, 8 pp.

In pressure-vessel design above certain proportions, the usual methods of providing for increased load capacity cannot be applied economically. Appreciable improvements in material economy can be accomplished by shrink-fit construction of pressure vessels requiring diameter ratios in excess of $R = 2.5$. A method for computing rational shrink-fit dimensions is presented. An example is demonstrated in which a reduction of wall thickness from 9.25 in. to 5 in. is accomplished. In this case, the working pressure and design stress are, of course, unchanged. No claim is made, however, that the method will result in the maximum material economy that may be possible.

From author's summary

3025. **Edmunds, H. G., Stresses due to shearing force in a holed plate,** *Engineer, Lond.* 199, 5177, 518–519, Apr. 1955.

It is sometimes necessary to bore holes in girder webs and there is an obvious need to know what stress distribution arises around such a hole. Toward the solution of this problem Tuzi analyzed the stresses around a circular hole in a plate in pure bending, and Neuber analyzed the stresses due to tension, bending, and shearing force around an elliptical hole. This article presents an alternative to Neuber's approach for the case of a circular hole under a shearing force, and the theoretical result is compared with a photoelastic investigation.

From author's summary

3026. **Argyris, J. H., Diffusion of antisymmetrical loads into, and bending under, transverse loads of parallel stiffened panels,** *Aero. Res. Counc. Lond. Rep. Mem.* no. 2822, 52 pp., May 1946, published 1954.

A general theory of diffusion of antisymmetrical concentrated end loads and arbitrary antisymmetrical edge loads into parallel stiffened panels is presented. The effect of arbitrary transverse loads is investigated. It is shown that the effect of transverse loads on the direct stresses in a parallel panel is equivalent to that of antisymmetrical edge loads producing the same bending moment at each section. The analysis is based on the assumption that the effective sheet area is concentrated at lines of attachment of the stiffeners and that the stiffeners are held apart by a closely spaced system of members, which are rigid against axial strain, but offer no resistance to bending in the plane of the panel.

It seems to the reviewer that, for stiffened thin sheet panels used in the conventional aircraft construction, the effective sheet area for stiffeners under compression may have to be treated as variable due to the change of effective width with compressive stress.

T. H. Lin, USA

3027. **Kalandiya, A. I., Solution of some problems for the flexure of an elastic plate** (in Russian), *Prikl. Mat. Mekh.* 17, 3, 293–310, May/June 1953.

Problems in thin-plate theory for supported boundaries are solved by analytical methods, based on the approach by N. I. Muskhelishvili. The cases considered refer to plates the boundaries of which may be mapped onto the unit circle by means of polynomials. The solutions are obtained via the problem of linear relationship in terms of power series and Cauchy integrals.

J. R. M. Radok, Australia

3028. **Salvadori, M. G., Shell versus arch action in barrel shells,** *Proc. Amer. Soc. civ. Engrs.* 81, Separ. no. 653, 10 pp., Mar. 1955.

Paper considers thin cylindrical shell of arbitrary cross section, stiffened by infinitely rigid transverse ribs. Shell is horizontal and built rigidly into foundation, with vertical tangents along built-in boundaries. It carries uniform vertical load which is transmitted to ground (a) directly (arch action), (b) via stiffeners (shell action). Paper evaluates these two actions. Analysis is entirely mathematical, using membrane theory. Table is given of (1) % total load carried directly by ground, (2) ratio of maximum shell moment to moment in a circular arch uniformly loaded.

These are expressed in terms of distance between stiffeners, radius and thickness of shell near ground, and span.
B. Noble, England

3029. Becker, H., Load distribution at the intersection of several coaxial axisymmetric shells, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-43, 3 pp.

A relaxation analysis of the load distribution at the intersection of several axisymmetric coaxial shells is presented. The relaxation process leads to an infinite power series, the summation of which yields explicit expressions for the individual shell loads. The shells are all assumed to be unconstrained axially, thus eliminating axial interaction effects among them. The analysis, consequently, is restricted to radial shear forces and distributed moments at the intersection line, which is taken in a plane perpendicular to the common axis of the shells. Methods of treating temperature and pressure effects are described, and an illustrative example of the analysis of a three-shell intersection is included.
From author's summary

3030. Weydert, J. C., Stresses in oval tubes under internal pressure, *Proc. Soc. exp. Stress Anal.* **12,** 1, 39–54, 1954.

Author presents an analytical and experimental investigation of stresses in thick-walled oval tubes. Analytical solution results from application of curved-beam equations with the actual shape replaced by combinations of arcs. Experimental results were obtained by photoelastic "stress-freezing" method. Paper includes design curves and discussion of test equipment. Experimental results confirm analysis to be valid for engineering applications.

Reviewer believes results to be strictly valid only for a narrow ring, rather than a tube, as this assumption is inherent in both the analysis and experiment.
W. E. Cooper, USA

3031. Karlsson, K. I., Simple calculation of deformation and stress in the shell of thin-walled cylindrical vessels (in Swedish), *Acta Polyt.* **3,** 4, 24 pp., 1954.

See AMR 8, Rev. 2322.

3032. L'vin, Ya. B., Calculation of cylindrical shell subject to cyclic edge effects (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **9,** 113–130, 1951.

Author investigates a space structure of the bunker type composed of two different thin-walled shells of revolution. The upper shell is circular and is joined to the larger end of another shell having the form of a truncated cone. At the juncture of the shells is a ring which is supported by columns equally spaced on its periphery. Function of the ring is to distribute the reaction forces and reduce stress concentrations in the shell at points of support.

Starting with Vlasov's equations for shells, author achieves simplification by reducing the eighth-order partial differential equation with real coefficients to a complex one of fourth order and, because of cyclical symmetry, the equation becomes ordinary. Roots of the characteristic equation are found, but end results are approximate, two terms in the series expansion being used.
S. Sergev, USA

3033. L'vin, Ya. B., Calculation of cylindrical shells subject to cyclic edge effects (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **17,** 59–68, 1953.

Author gives exact solution to a space structure previously discussed by him. The structure is of the bunker type with a circular cylindrical shell above joined by a ring to the larger end of a truncated conical shell. The ring is supported by columns equally spaced on its periphery. The purpose of the ring is to distribute the reaction forces of the columns, thus reducing the stress concentration in the cylindrical shell.

Detailed discussion and general principles needed to solve the problem are given in author's first paper (see preceding review) which is indispensable to understanding the discussion in this work.
S. Sergev, USA

Buckling Problems

(See also Rev. 3014)

3034. Mackey, S., Investigations into the strength of short reinforced concrete columns. Parts I, II, *Civ. Engng. Lond.* **49,** 579, 580; 945–948, 1084–1085, Sept., Oct. 1954.

An investigation into the effect of L/D ratio and percentage of lateral reinforcement on the ultimate load of short reinforced-concrete columns. A total of 90 columns was tested, 3.5 in. square, in lengths from 12 to 36 in., with p from 0 to 6.4%, and with various gages and pitch of lateral ties.

Columns with an L/D of 10.3 failed in bending at an ultimate load of about 85% that of the columns with an L/D of 3.4. Tied columns require a minimum percentage of lateral steel to develop the yield strength of the longitudinal reinforcement. Additional lateral steel beyond the minimum will increase the ultimate load capacity; with high tensile longitudinal reinforcement, an increase in the lateral steel will increase the ultimate column load.
I. A. Benjamin, USA

3035. Gatewood, B. E., Buckling loads for beams of variable cross section under combined loads, *J. aero. Sci.* **22,** 4, 281–282, Apr. 1955.

Note in Readers' Forum.

3036. Wittrick, W. H., Buckling of oblique plates with clamped edges under uniform shear, *Aero. Quart.* **5,** part 1, 39–51, May 1954.

The Rayleigh-Ritz method is used to determine buckling stress in shear for clamped oblique plates having an angle of obliquity of 45° and side ratios of 0.6, 0.8, 1.0, 1.25, and 1.667. Iguchi functions are used to express the deflections. An eighth-order determinant is found to give satisfactory results for the smaller critical stress (shear tending to increase obliquity), while even a twelfth-order determinant gave inadequate convergence for the larger critical stress (shear tending to decrease obliquity). A comparison is given with earlier results for plates having other boundary conditions.
S. Levy, USA

3037. Raville, M. E., Analysis of long cylinders of sandwich construction under uniform external lateral pressure, *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1844, 23 pp., 5 figs., Nov. 1954.

At first the case of a long cylinder under uniform external pressure is solved by assuming that the core carries only radial compression and that the face material carries tangential and radial stress, both of which act at the middle surface of the faces. The solution is effected by satisfying boundary conditions of stress and displacement at the interfaces between core and skin. The

only material constants involved are the compressive moduli of elasticity of face and core material.

The problem of buckling is solved by assuming the cylinder has buckled slightly into n half-sine waves, thus superimposing small, additional nonaxisymmetric stresses and displacements. The additional core stresses consist of small radial normal stresses and small radial and tangential shear stresses. Additional face stresses are small radial and tangential normal stresses and a tangential shear stress, all of which act at the middle surface. The solution is obtained by satisfying boundary conditions of stress and displacement at the interface as before. Three equations involving three constants result. The buckled form is obtained by equating the determinant, composed of the coefficients of the constants, to zero. A quadratic equation results, involving n, the critical pressure, compressive moduli of elasticity of core and faces, the core shearing modulus of elasticity, and the dimensions. For the practical range of sandwich construction, the smaller of the two roots may be obtained with sufficient accuracy by neglecting the second-degree term. This solution can also be applied to semi-infinite hinged cylindrical sandwiches.

No computations are included as these are to be presented in a later report in which the stability of cylinders of finite length will be investigated. On page 10, the equation below Eq. 31 should contain the subscript 4 instead of 1.

N. C. Costakos, USA

3038. Gerard, G., Buckling efficiencies of plate materials at elevated temperatures, *J. aero. Sci.* **22**, 3, 194–196, Mar. 1955.

Author considers the buckling efficiencies of various plate materials in the elastic and plastic ranges at elevated temperatures. The efficiency in the elastic range is related to the elastic modulus and the compressive yield strength at the particular temperature in question. For a plate that buckles plastically, the failure stress can be obtained by substituting the proper secant modulus for the elastic modulus. Using the appropriate values of the compressive yield strength and the moduli, the relative weight-strength efficiencies of plates of various materials were calculated. Materials in question were 75S-T6, 24S-T4, and XA78S-T6 aluminum, RC-130-A titanium, stainless W, and Inconel X. Considering elastic buckling, it was found that the alloy XA78S-T6 is most efficient up to 400 F. Between 400 and 970 F, RC-130-A is superior, and beyond 970 F, Inconel X is the most efficient material. Considering plastic buckling, it is found that the aluminum alloy XA78S-T6 is efficient to 250 F, after which 24S-T4 is superior up to 700 F. The titanium alloy is efficient beyond 700 F to approximately the end of its range, which is approximately 900 to 1000 F.

A. D. Schwope, USA

3039. Okamura, T., Torsional buckling of welded built-up members, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952: Nat. Committee for Theor. appl. Mech., May 1953, 149–150.

Paper deals with the design of columns of welded built-up sections composed of one web, as, for example, unsymmetrical I-section loaded in the plane of the web. Under these conditions, buckling in the lateral direction is combined with torsion of the column, and the buckling load is generally different from the Euler buckling load.

From author's summary

3040. Nash, W. A., Effect of large deflections and initial imperfections on the buckling of cylindrical shells subject to hydrostatic pressure, *J. aero. Sci.* **22**, 4, 264–269, Apr. 1955.

Investigation of the effect of initial imperfection on the buckling of cylindrical shells with a large deflection theory is extended to the case of hydrostatic loading. It is found that the number of circumferential waves can be predicted with sufficient accuracy by a small deflection theory. However, good agreement of calculated peak pressure with observed experimental results may be obtained by the inclusion of an "unevenness" parameter, which is a function of the geometry of the shell. A value of 3×10^{-4} is suggested. This value is somewhat greater than existing recommendations for cylinders subject to axial compression or torsion.

C. C. Wan, USA

Joints and Joining Methods

(See also Rev. 2960)

3041. Kawada, Y., On the strength of bolts used in connecting rods, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 187–190.

Author cites observation that connecting-rod cap-bolt failures are judged to have inception in thread-root on inner side of bolt at bearing face of nut. He carries out conventional stress analysis of setup assuming (1) bolt and cap elastic, yoke-end of rod rigid; (2) stem of bolt does not contact inside of hole in rod-yoke or cap-pad; (3) bearing pressure in cap distributed cosine-wise over arbitrary segment, invariable during bending; (4) no initial torquing on cap bolts.

Elastic conditions are established for cap- and bolt-end rotations and translations based on both planar and point contact between bearing face of nut and cap pad. In former case, solutions are made for linear displacement to pad-normal bearing force and magnitude of pad-tangential force. In latter case, pad-normal force is assumed at edge of nut, solution for pad-tangential force and relative angular displacement of nut and pad.

Four configurations, claimed representative of automobile engine, are calculated. Results indicate (1) bending stress five to six times direct stress; (2) for constant cap thickness, bending stress increases directly with bolt diameter; (3) for constant bolt diameter, bending stress increases inversely with cap thickness.

P. R. Hardesty, USA

3042. Stoy, W., and Mlynek, F., Contributions to load-carrying capacity of joints of various wood species assembled with high-carbon-steel nails (in German), *Holz als Roh- und Werkstoff* **12**, 10, 391–402, Oct. 1954.

With the introduction of high-carbon-steel nails in recent years, it became desirable to determine the load-carrying capacity of joints assembled with nails made from steel of low- and high-carbon content. The tests described were performed on three-member joints with 8d plain-shank nails in double shear. The wood species used ranged from the relatively low-specific-gravity fir to higher-specific-gravity beech plywood and to high-specific-gravity African Bongossi. The fir joints were assembled with green 1-in. lumber and tested immediately or after seasoning of the nailed joints or assembled with dry 1-in. lumber and tested immediately.

Load-deformation diagrams indicate the considerable influence of nail and lumber quality on both stiffness and load-carrying capacity of nailed joints. It was found that high-strength plain-shank nails can become fully effective only in high-strength lumber. On the other hand, if the carbon content of the steel is too high, the load-carrying capacity of the joint can be even decreased. Depending on depth of nail penetration and lumber quality, the nail head becomes more or less effective.

The information presented throws considerable light on the action of plain-shank nails in lumber joints. It would have been desirable to have had the study extended to joints assembled with

properly threaded nails, since the commercially available, threaded, high-carbon-steel nail can provide considerably greater load-carrying capacity even in commercial structural lumber than the plain-shank nail of steel of same carbon content.

E. G. Stern, USA

3043. Orman, H. R., Holding power of staples in creosoted posts, *Forest Products Research Notes (New Zealand)* **1,** 4, 11–17, 1952.

The holding power of conventional, U-shaped, fence staples in creosote-impregnated fence posts was found to be 25% smaller in such posts than in nontreated posts. Barbed staples provided smaller holding power in nontreated and treated posts than plain-shank staples. Because of the insufficient holding power of conventional U-shaped staples in treated posts, L-shaped staples with a threaded long leg were introduced in the United States since this paper was published in New Zealand.

E. G. Stern, USA

3044. Samans, W., and Blumberg, L., Endurance testing of expansion joints, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-103, 19 pp.

In the absence of specific rules for the design of expansion joints to be used in the elements of pressure vessels, under the rules in the ASME Boiler and Pressure Vessel Code, and in order to assist in the formulation of more definite rules in the text of the codes concerned with expansion joints, based on the needs under service conditions, endurance studies and tests were made of a number of commercial types of expansion joints.

From authors' summary

3045. Kubo, K., Mechanical properties of connection angles, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committtee for Theor. appl. Mech., May 1953, 97–99.

Structures

(See also Revs. 2982, 3014, 3015, 3026, 3034, 3039, 3040, 3043, 3056, 3079, 3130, 3237, 3247)

3046. Charlton, T. M., Model analysis of structures, New York, John Wiley & Sons, Inc., 1954, xii + 142 pp. $5.

Book is written for practicing engineers and advanced students. It is mainly concerned with the theoretical principles and techniques of the Begg method of experimental analysis of plane structural models. It presents also the method in which the Ruge moment indicator is used. Reference is made to the use of compensating balances to avoid the effect of creep and to a dynamometer, devised by the author, for finding forces and moments developed in the sections of a model. M. Rocha, Portugal

3047. Riesz, G. W., and Swain, B. J., Structural analysis by electrical analogy, *Proc. Soc. exp. Stress Anal.* **12,** 1, 13–22, 1954.

The potential distribution obtained when currents are introduced along a string of resistors connected in series is analogous to the bending moment diagram due to forces applied at similar points on a beam. Externally applied moments (such as end moments for built-in beams) are represented by applied voltages. For the beam, the redundants are determined by Castigliano's minimum strain-energy theorem. A similar energy state is obtained in the analog by grounding through small capacitors the junctions between the resistors. The current (force) or voltage (moment) chosen as the redundant is adjusted until an impedance bridge indicates minimum reactive power in the analog. The answers to the beam problem are now the currents and voltages measured in the analog. Influence lines of reactions for the 650-ft Raritan River bridge obtained with this model and by calculation show excellent agreement. W. W. Soroka, USA

3048. Serwe, J., Analog iterator (in German), *Stahlbau* **23,** 12, 293–296, Dec. 1954.

Design of a manually operated mechanical computer for solution of continuous beam by iteration is described. Author shows how this machine can be modified for analysis of frames.

Computer is fairly complex and does not have any advantages over more convenient electrical system. E. G. Newman, USA

3049. Benthem, J. P., Note on minimizing a quadratic function with additional linear conditions by matrix methods, with application to stress analysis, *Nat. LuchtLab. Amsterdam Rep.* S.437, 8 pp., Aug. 1954.

The complementary energy of an n-fold statically indeterminate structure is expressed as a function of m unknown generalized forces ($m > n$). The m forces are determined that minimize the complementary energy, subject to the condition that these forces satisfy m-n equilibrium equations. The method requires inversion of lower order matrixes than when Lagrangian multipliers are used. From author's summary by Y. L. Luke, USA

3050. Mehmel, A., On the bases of the n and n-free methods of design of reinforced-concrete sections subjected to bending (in German), *Beton u. Stahlbetonb.* **50,** 2, 51–54, Feb. 1955.

Paper describes design of reinforced-concrete sections with and without a fixed n, n being ratio of moduli of elasticity of steel and concrete. The n-method thus means linear stress-strain curve for concrete, whereas in n-free method more realistic shape of stress-strain diagram and curved stress distribution in compression zone of section are used. The n-free method gives 20–25% higher calculated carrying capacity of beam.

Author discusses shape of stress-strain curve of concrete and other materials which can be concave as well as convex toward the strain axis, depending on the type, duration, and repetition of loading. The stress-strain curve thus is no longer a material constant. The stress safety factor used in the German specification DIN 4227 is 1.75, whereby the strength of concrete is based on 2/3 of average cube strength to account for greater variability of concrete compared to steel.

Author concludes that before the n-free method can be adopted for nonprestressed concrete, more research is needed, mainly on shape of stress-strain curve in relation to type of loading and the assumption that all concretes have the same ultimate compression strain, and because the n-free method results in up to twice as much reinforcing in balanced design.

W. R. Schriever, Canada

3051. Kirchner, G., Stress distribution in transversally prestressed slabs (in German), *Beton u. Stahlbetonb.* **50,** 2, 61–64, Feb. 1955.

The stress distribution is derived from investigations on an infinitely long strip. From the results, it can be concluded that

the distribution remains uniform even if the distances of transverse anchorages were increased over the generally used ones. In any particular practical case the effect of the floor beams and stringers as well as the effect of continuity should be taken into account. From author's summary by D. Vasarhelyi, USA

3052. Samuely, F. J., Structural prestressing, *Struct. Engr.* 33, 2, 41–54, Feb. 1955.

3053. Klein, B., and Cox, H. L., Approximate structural analysis by the method of collocation, *J. aero. Sci.* 21, 10, p. 719, Oct. 1954.

Note in Readers' Forum.

3054. Wise, J. A., Dynamics of highway bridges, *Nat. Res. Counc. Highway Res. Bd. Proc. 32nd Ann. Meet.*, 180–183, 1953.

A theoretical study of experimental data relating to the dynamic response of a deck-steel-girder continuous highway bridge to moving loads is presented. A study of the theoretical stresses and a comparison of theoretical and experimental static and dynamic stresses are included.

The bridge investigated is a seven-span, continuous, steel-girder bridge with two reinforced-concrete approach spans, totaling 800 ft in length and 36 ft wide. The concrete deck is bonded and anchored to the top flange of the steel girders. There are eight longitudinal steel girders connected by rigid steel-girder transverse diaphragms. Four transverse diaphragms were used in the five 100-ft spans and three diaphragms in the two 80-ft end spans.

Loads used for the tests were one Euclid earth mover of gross weight 51,500 lb, and one loaded White truck of gross weight 30,250 lb. Electrical resistance, SR-4 strain gages were used to measure stresses at 116 points. Both static and dynamic stresses were measured. Dynamic stresses were recorded on a cathode-ray oscilloscope, whose screen was photographed.

The measured static stresses were in excellent agreement with the theoretical stresses. The basic elementary theory used for the static stress analysis assumed that the diaphragms were rigid and distributed the load in any lane to all the girders. The diaphragms were found to be completely effective.

The dynamic stresses were not proportional to the static stresses nor were they distributed among the girders in the same way. The tests indicated that the AASHO impact formula tended to overestimate the impact effect by about 50%.

A tentative impact formula is suggested in the paper.

From author's summary

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3036, 3038, 3069, 3075, 3076, 3078, 3080, 3085)

3055. Noll, W., On the continuity of the solid and fluid states, *J. rat. Mech. Analysis* 4, 1, 3–81, 1955.

In this ample and interesting paper author generalizes, for three-dimensional bodies, the model proposed by Maxwell for one-dimensional *hygrosteric bodies* (the bodies called hygrosteric are a class of materials including solids and fluids). As is well known, the motion equation and the continuity equation are not sufficient to determine the motions of continuous media. We must have in addition certain constitutive equations (c. eq.) able to characterize the particular materials studied.

In general, the c. eq. are established with thermodynamical considerations. On the contrary (chap. 2), author investigates c. eq. as partial differential equation which must be invariant under particular transformations, according to the principle of isotrope and homogeneity of space, established by author in chap. 1. In chap. 3, in conformity with the special forms of the c. eq., author gives a classification of the hygrosteric bodies, and he points out the connection with elastic solids and with viscous fluids. In a special case he obtains the theory of the *linear fluent bodies*, for which Zaremba had established the first rigorous three-dimensional generalization of Maxwell's model. In chap. 4, author studies the solutions of some special interesting cases (homogeneous stress, steady linear flow, Poiseuille flow, etc.).

G. Sestini, Italy

3056. Baldauf, H., Approximative calculation of decrease of "prestress" through creep and relaxation of multilayer members (in German), *Beton u. Stahlbetonb.* **49**, 9, 214–216, Sept. 1954.

Author's formulas replace simultaneous differential equations for the approximate calculation of losses due to creep and shrinkage for structures prestressed in their completed state with the entire dead weight available and the superimposed load occurring occassionally, as with bridges. The exponential equations are quite correct if tensioned steel is in one layer.

Reviewer believes that all exact formulas, including this approximation, are of use only if the designer knows beforehand the humidity and temperature at the various stages, so as to consider these in the exponential equations. Otherwise, it is preferable to base losses on the worst conditions, using simple formulas. P. W. Abeles, England

3057. Marin, J., Interpretation of creep and long-time test data, *Proc. Soc. exp. Stress Anal.* 11, 2, 207–212, 1954.

Total creep strain ϵ is represented by a relation of the form $\epsilon = DS^m + BtS^n$, where t is time, S = stress (constant) and D, B, m, n = material constants. Formula is proved to represent published creep test data for a number of materials.

F. K. G. Odqvist, Sweden

3058. Orr, R. L., Sherby, O. D., and Dorn, J. E., Correlations of rupture data for metals at elevated temperatures, *Trans. Amer. Soc. Metals* **46**, 113–128, 1954.

Stress-rupture data for pure metals and high-strength alloys at elevated temperatures are correlatable by means of the equation $t_r e^{-\Delta H_r/RT} = f(\sigma)$, where σ is the applied stress, T the absolute temperature, t_r the time to rupture, R the gas constant, and ΔH_r the activation energy for rupture. These correlations are successfully applied to data for aluminum, beryllium, titanium, nickel, niobium, molybdenum, and several representative high-strength commercial alloys. ΔH_r is found to be a constant for a given metal, and for relatively pure metals is believed to be equal to the activation energy for creep and self-diffusion.

From authors' summary by T. J. Dolan, USA

3059. Brunot, A. W., High temperature test data, *Proc. Soc. exp. Stress Anal.* **11**, 2, 213–216, 1954.

Review of new testing methods such as "stepdown relaxation" tests and constant load creep tests with superimposed vibrations which have been devised in order to provide information necessary for designers of high-temperature machinery.

F. K. G. Odqvist, Sweden

3060. Sherby, O. D., and Dorn, J. E., An analysis of the phenomenon of high temperature creep, *Proc. Soc. exp. Stress Anal.* **12,** 1, 139–154, 1954.

Total creep ϵ at constant stress σ and variable temperatures for the whole strain range up to rupture at strains of the order of 100% may be represented by an equation $\epsilon = f(\theta, \sigma)$, where θ is a "temperature-compensated time parameter" $\theta = {}_0\int^t \exp(-\Delta H_c/RT)dt$, with t = time, R = gas constant and ΔH_c = activation energy for creep. Experimental data by authors and others support above equation. In particular, ΔH_c proves to be a constant for a given metal and insensitive to dilute solution alloying (verified on Al-alloys), grain size, dispersions of stable intermetallic compounds, cold-working, temperature, stress, and structure. Creep rupture is found to occur at a critical value of θ calculated with the same value of ΔH_c, thus proving the intimate physical relationship between creep and rupture. ΔH_c, as determined from creep curves, shows close correlation with activation energy for self-diffusion and with melting temperature of metal.

A model for creep is presented wherein it is suggested that the rate-controlling process is that of recovery of barriers from the path of moving dislocations and that the removal of these barriers is controlled by atomic diffusion processes.

F. K. G. Odqvist, Sweden

3061. Sorokin, O. V., On expression of stress relaxation curves for metals by exponential functions (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 11, 1616–1617, Nov. 1953.

Author investigates two Oding's exponential equations of stress relaxation in metals in an effort to establish a degree to which these equations reflect the relaxation process. Stress $\sigma(t)$ at any instant t is equal to the reduced initial stress σ_0. The reduction factor is an exponential function with the base e. The exponent is a ratio, with the negative sign, of t and $n(t)$. Author defines the function $n(t)$ as a relaxation time and finds a relationship between $n(t)$ and t. Since the relaxation curve is exponential, then the logarithmic derivative of stress, taken with the negative sign, will be equal to the inverse of n. This quantity is known as the speed of the relaxation process. If the exponential function does not coincide with the relaxation curve, then the curve representing this function will have one more intersection with the relaxation curve in addition to the initial common point. Hence the entire actual relaxation curve may be represented by a family of exponential functions. Then each point on a curve is defined by an exponential with a particular value of $n(t)$ which reduces the initial stress σ_0 at instant t to actual value $\sigma_0(t)$. Author observes that, as a rule, such equations correctly reflect the relaxation process in metals.

V. A. Valey, USA

3062. Rovinskiĭ, B. M., and Liuttsau, V. G., Poisson's ratio in stress relaxation (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 10, 1471–1474, Oct. 1953.

Working with aluminum and copper and confining relaxation process to room temperatures, author experimentally developed a method of obtaining relaxation curves. The technique is based on determining transverse strain as a function of time while the initial elongation of a specimen remains constant, and then obtaining the Poisson coefficients also as a function of time. The initial longitudinal strain is made up of elastic and plastic strains.

Author makes the following observations:

(1) During stress relaxation, elastic strain decreases while residual strain increases. By extrapolation a relationship is found for determining Poisson coefficient at the instant of loading and prior to relaxation.

(2) For elastic strains and small limiting loads, the ratio of transverse compression is probably equal to 0.25.

(3) For plastic regions the Poisson ratio is 0.5. Technically, this is hardly attained.

(4) An important technical sense of Poisson coefficient follows from its additive nature. This provides a relation of elastic and plastic strains at the time of securing experimental data.

(5) Attempts to establish a relation between Poisson coefficients for pure materials and their position in the periodic chart lacks sound physical support since Poisson coefficients are dimensionless mechanical constants rather than physical properties.

(6) Poisson values for certain materials are not constant when observed experimentally.

Author concludes that experimental Poisson values are determined by the magnitude of applied loading and the relaxation properties of specimens. Author recommends that the existing data in handbooks be considered with certain criticism.

V. A. Valey, USA

3063. Rovinskiĭ, B. M., and Rybakova, L. M., Structural changes in metals under conditions of creep (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 9, 1241–1247, 2 plates, Sept. 1953.

Investigation was conducted for different residual deformations. Armco Iron (at 400 and 450 C) and EIa-1T Steel (at 575 and 625 C) were used. Analysis of structural changes in crystal grains by quantitative methods alone do not sufficiently reveal the peculiarities to differentiate creep from plastic deformation. Authors used qualitative analysis by x ray. They provided detailed description of the methods and made the following observations. Qualitatively the structural changes produced by creep are analogous to those due to plastic deformation. The changes which correspond to the same residual deformation, in both processes, become less obvious as temperature increases. Results of investigation of the crystal lattice deformation and the development of the microstresses under creep appear to support the conclusions which are based on the comparison of the structural changes due to creep and plastic deformation. Lattice deformation and microstresses occur as residual deformation increases. This is observed under creep as well as under plastic conditions. As temperature increases these processes are slower for creep. Considerably slowed down is the deformation of the lattice pattern.

V. A. Valey, USA

3064. Hult, J., Mechanism of creep (in Swedish), *Tekn. Tidskr.* **85,** 10, 199–204, Mar. 1955.

3065. Prager, W., Theory of plastic plates (in French), *Bull. tech. Suisse Rom.* **81,** 6, 85–90, Mar. 1955.

The yield condition and flow rule are derived for a rigid plastic plate in terms of the radial and circumferential moments and the deflection rate. Examples of finding the load-carrying capacity are given. An illustration is given for determining a lower bound on the minimum weight of a plate. Large deflections are discussed briefly and a comparison of theory and experiment are made. An example is given of a dynamic load problem in which a load greater than the collapse load is applied for a very short time.

The paper contains little that has not been previously presented by the author and his associates at Brown University [AMR 7, Revs. 1492, 1752; AMR 8, Rev. 1003; *Brown Univ. Reps.* DA 798-11, OOR-3172/4, OOR-3172/5]. However, in the words of the author, "A survey . . . is offered in the present paper

as a convenient introduction to the study of the work presented in greater detail in a number of recent papers and reports, some of which are not readily accessible." P. G. Hodge, Jr., USA

3066. Gotusso, G., On the behavior of continua beyond the elastic limit (in Italian), *R. C. Ist. Lombardo Sci. Lett., Cl. Sci. Mat. Nat.* (3) **17,** (86), 384–406, 1953.

Paper discusses the derivation of equations governing the deformation of continua beyond the elastic range. Various types of mechanical behavior are considered and attention is directed especially toward the inclusion of time effects, but, essentially, the material presented is standard. H. G. Hopkins, England

Failure, Mechanics of Solid State

(See also Revs. 3020, 3022, 3038, 3041, 3057, 3059, 3060, 3085)

3067. Millard, D. J., The cracking of layers of brittle material by differential strains, *Brit. J. appl. Phys.* **6,** 4, 124–127, Apr. 1955.

The cracking of a brittle layer of elastic material due to differential straining has been investigated as a function of a given strain pattern. An analysis of the stress equations leads to the conclusion that two dimensionless parameters only are involved, the ratio of the applied strains to the breaking strain and the ratio of the crack spacing to the layer thickness; the shape of the curve relating these parameters is deduced by physical argument and agrees with experiment.

From author's summary by R. Smoluchowski, USA

3068. Felix, W., and Geiger, Th., Brittle fracture of steel (in German), *Schweiz. Arch.* **21,** 2, 33–49, Feb. 1955.

First part of the paper deals with research on process of fracture in the notch impact test for mild steels, especially in the lower range of impact strength. The important questions of nearly total cleavage fracture, and possible shear deformation of crystals accompanying such fracture, are discussed on the basis of results from x-ray diffraction analysis. It is found that it can be correct to look upon total brittle fracture as a matter of mixed fracture, because of the fact that the ruptured material shows a mixture of cleavage and shear deformation within micro-small areas of structure.

Second part of the paper describes an actual case of total brittle fracture in service. With the aid of x-ray and microhardness investigations, authors show quite clearly that the question of cleavage and plastic shear has to be referred to the scattering orientation of crystals in relation to the direction of active forces on the stressed body. R. Nilson, Sweden

3069. Gibb, C. D., Report on investigation into the failure of two 100-mw. turbo generators, *Engng. J., Montreal* **38,** 3, 213–236, Mar. 1955.

In the Toronto power station, the 100-mw 1800-rpm unit no. 1 exploded on 1st April 1954, followed four days later by a similar failure of unit no. 2. Detailed physical and metallurgical investigations carried out by the Parsons Works, England, and other research laboratories clearing up the possible causes of this serious failure are presented in the paper. It is stated that in both cases the failure occurred by cracking of the rotor end bells made of nonmagnetic steel in order to reduce the leakage fluxes at the ends of the stator core.

Forged under a 4000-ton press, this material being austenitic, the physical properties required cannot be obtained by heat treatment and residual stresses are inevitable. The effect of ventilating holes gives rise to stress concentration of a high order. Cyclic fatigue tests carried out under similar conditions on other end bells showed that such failures could be brought about artificially. The end bells have been replaced on the new rotors with new ones made of chrome molybdenum magnetic alloy omitting the ventilating holes, as direct cooling of the rotors was introduced at the later constructions.

The investigations, which are of high scientific value, gave results to be used widely in large turbine generator design.

A. Lenkei, Hungary

3070. Nakanishi, F., Endurance limits of beams of various cross-sections under cyclic bending, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 175–178.

Results of fatigue tests with mild steel beams of several cross sections are compared with author's theory.

A. Phillips, USA

3071. Hughes, G., and Spurr, R. T., An experimental investigation of non-metallic wear, *Proc. phys. Soc. Lond.* (*B*) **68,** 422B, part 2, 106–110, Feb. 1955.

Wear per unit sliding distance was found to be proportional to load and inversely proportional to hardness of the softer material for Montan wax, the hardness being varied by a factor of four by changing the test temperature. R. B. Green, USA

3072. Young, W. E., Hershey, A. E., and Hussey, C. E., Jr., The evaluation of corrosion resistance for gas-turbine-blade materials, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-215, 15 pp.

Surface analysis of gas-turbine-blade material before and after exposure to the combustion products of residual fuel oils demonstrates the corrosive effect of these products, and a measurable indication may be obtained in a fraction of the testing time required to produce appreciable weight loss. Surface analysis has the further advantage that it is possible to measure corrosion in specific regions on a specimen where the specimen has been exposed to a gas-flow pattern with a well-defined temperature profile. Weight-loss measurements following long-time tests have shown good agreement with this method of analysis. The fusion temperature of the fuel ash appears to be a reliable criterion for judging the potential corrosivity of residual fuel oil, and good correlation has been obtained between ash-fusion temperatures and corrosion, both for untreated oils and oils with additives.

From authors' summary

Material Test Techniques

(See also Revs. 3022, 3056, 3059, 3063)

3073. Davis, H. E., Troxell, G. E., and Wiskocil, C. T., The testing and inspection of engineering materials, new 2nd ed., New York, Toronto, London, McGraw-Hill Book Co., Inc., 1955, xv + 431 pp. $6.50.

Primary aim of this text is to provide a thoroughgoing treatment of mechanical testing of engineering materials, from the general principles involved to specific applications and problems encountered, including those of inspection. Need for testing is

brought out in first chapter through discussion of general features of engineering materials, their uses and selection. Second chapter introduces various mechanical properties and commonly used methods of investigating them. In chap. 3, apparatus used in testing laboratories is described. Following this is a series of six chapters, each discussing in detail certain related mechanical tests including tension, compression, shear, bending, hardness, impact, fatigue, creep, and nondestructive tests. General pattern consists of following parts: discussion of behavior of materials with reference to mechanical property under consideration; section on scope and applicability of tests; detailed description of test itself; and finally, careful consideration of effect of important variables and limitations of the test. A chapter on analysis and one on principles of inspection complete this part of text.

In part 2, a list of 24 problems with instructions for laboratory work is provided. Appendix gives concise summary of important properties of many commonly used materials.

Second edition is substantially same as the first ("Preliminary Edition") which was brought out in 1941 for engineering defense training courses but lasted for fourteen years, through at least eight printings. Principal changes are eight new articles on electric resistance wire strain gages, introduction to brittle coatings, a very brief discussion of true stress-strain tests, and frequent references to various new testing methods and techniques. A number of articles are partially rewritten to bring them up to date, and a number of new graphs are included which help present a clearer picture of certain variations. The change that will probably be found most useful by students is addition of an index. Reviewer would like to see a few other minor changes, such as substitution of γ for ϕ, for shearing strain, and G for E_s, for shearing modulus.

Reviewer feels that its comprehensive treatment of the subject makes this book unusually versatile as a text for a wide range of laboratory courses in materials testing. Only drawback is that it may seem *too* comprehensive to some, especially those with short courses, in which reading assignments must be short and concise. Its great thoroughness, however, recommends it as an excellent reference book for all who are interested in mechanical properties of materials and experimental methods of investigating them.

C. W. Richards, USA

3074. Nakagawa, Y., On the nature of the Shore hardness, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 197–200.

Author studies, by analytical and experimental methods, the relationship between the Shore hardness determined dynamically and hardness determined statically, and various factors which affect the Shore hardness. He shows analytically that the Shore hardness is proportional to the ratio between the Brinell hardness and the elastic deformation under load. Thus, for a material such as steel whose hardness can be widely varied by heat-treatment but in which the elastic properties remain unchanged, the Shore hardness differs from the Brinell hardness by a single experimentally determined constant.

Experimental results on the variation of static hardness with load show that for light loads the hardness increases as the load is increased. The rate of increase, however, diminishes until a constant hardness is reached. To this behavior is related the decrease in the Shore hardness number in the range of large falling heights of the tup.

Author investigated a number of factors which were suspected of causing energy losses and, therefore, diminishing the rebounding height. He concludes that measurable energy losses are caused by two factors. The first is contact between tup and inner wall of glass tube in the Shore scleroscope tester, and the second is the resistance of air escaping between falling tup and wall.

F. Garofalo, USA

3075. Nakagawa, Y., Okuda, S., and Matsui, K., On the impact hardness, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 201–204.

In this investigation, authors explore more thoroughly a number of factors encountered in determining the Shore hardness and in interpreting its physical meaning.

The test apparatus consists of a pendulum-type hardness impact tester. A ball, $1/2$ in. in diameter or smaller, embedded in the striking hammer is used for making the impression. The dimensions of the impressions as well as the rebounding angle are measured directly.

An analytical presentation is offered of the relationship between load and depth of indentation under dynamic and static conditions. It is assumed in this presentation that this relationship for dynamic and static loading differs only in the constants. Experimentally it is found that one of the two constants in the relation for static loading is equal to its corresponding constant in the relation for dynamic loading. The ratio of the additional constants is invariant with depth of indentation. It is found that, for the same depth of indentation, the force under dynamic conditions must be greater, than under static conditions. The difference found is greater the greater the weight of the hammer.

A graphic method was used to determine the total depth of impression, including plastic and elastic deformations. For small loads under dynamic conditions the fractional elastic strain decreases with increasing load and eventually levels off at about 4000 kg.

For three hammers of different weight, the ratio of the falling height of the hammer up to 350 mm to the rebounding height remains essentially constant. The rebounding height also remains unchanged when changing the ball size between $1/2$ in. and $5/32$ in. in diam. Reducing the size to $1/8$ in. decreases the rebounding height.

F. Garofalo, USA

3076. Garofalo, F., Malenock, P. R., and Smith, G. V., Hardness of various steels at elevated temperatures, *Trans. Amer. Soc. Metals* **45,** 377–396, 1953.

A new hot hardness tester is described. The machine is based on the Vickers principle, a static load on a pyramid-shaped indenter being used. Details of construction and technique are given. Results of tests in some carbon steels and 18Cr-8Ni austenitic stainless steels are shown for temperatures up to 1500 F. Effects of surface preparation and duration of loading are discussed. Experimental relationships were found between hot hardness and creep rupture properties.

C. E. Turner, England

3077. Griangreco, E., Experimental investigation of the creep of cement (in French), *Ann. Inst. tech. Bât. Trav. publics* **7,** 79/80, 666–676, July/Aug. 1954.

Research on creep demands a large number of test specimens and, as a consequence, testing equipment is occupied for a long period of time. The device used by author is simple and not cumbersome. It consists of an annular cylindrical specimen whose ends are in contact with nuts fastened to a steel rod passing through the hole in the specimen. In this way, the tension to which the steel rod is subjected through the tightening of the nuts causes compression in the cylindrical specimen. The length of the device is easily measured by means of a shrinkage meter.

When, as the result of creep, the compressive stress falls, it is possible to bring it back to the initial value by tensioning the steel rod in a machine and by tightening the nuts.

The development of this method is described in this report, using a specimen of neat cement paste. The preliminary results are encouraging, but they are not very numerous and are given primarily as an indication and as justification of the method. Different graphic representations of the phenomenon are also submitted.

From author's summary

3078. **Pao, Y.-H., and Marin, J., A new dynamic creep testing machine,** *Proc. Soc. exp. Stress Anal.* **11,** 2, 107–114, 1954.

Paper describes a 4-unit creep-testing machine in which a specimen may be subjected to a fluctuating load consisting of a mean static load and an alternating load. The machine may also be used for constant-load creep tests.

In the case of the dynamic tests, the magnitude of the mean static load is maintained constant throughout the test and is unaffected by changes in length or stiffness of the specimen under test. Unlike previous machines developed for dynamic creep tests, the mean static load is maintained constant in this machine by dead weights acting through a lever arm.

From authors' summary

3079. **Beyer, F. R., and Lebow, M. J., Long-time strain measurements in reinforced concrete,** *Proc. Soc. exp. Stress Anal.* 11, 2, 141–152, 1954.

The deformations and mechanical strength of reinforced-concrete structures immediately after set are not generally known. To obtain data concerning this behavior relevant to structural design procedures, measurements were made with electrical strain gages of the stress distribution in an actual building during and after its construction. Data were recorded essentially on a continuous basis with instruments of proved reliability, and results have been analyzed to indicate the strain-time relationship in the reinforcing steel.

From authors' summary

3080. **Pao, Y.-H., and Marin, J., A six-unit universal creep testing machine for plastics,** *Proc. Soc. exp. Stress Anal.* **11,** 2, 185–196, 1954.

Paper describes an automatically controlled six-unit testing machine designed for testing plastics. The machine may be used for carrying out any one of the following types of tests: (a) constant-load creep tests, (b) constant-stress creep tests, (c) stress-relaxation tests, (d) constant strain-rate stress-strain tests, and (e) tests in which either the load or the deformation is made to vary as a prescribed function of time. In most of the foregoing tests, the specimen may be subjected to either simple tension, simple compression, pure bending, or pure torsion.

Unlike previous machines of this type, this machine has six loading units, thereby making it possible to accomplish more extensive long-time creep testing in a given time interval.

From authors' summary

3081. **Roberts, H. C., and McDonald, V. J., Control and programming of a 200,000-pound fatigue machine,** *Proc. Soc. exp. Stress Anal.* **11,** 2, 1–10, 1954.

3082. **Benda, E. K., and Gallant, R. A., An automatic load control for fatigue test equipment,** *Proc. Soc. exp. Stress Anal.* **12,** 1, 209–214, 1954.

3083. **Hewson, T. A., Further notes on automatic control as applied to fatigue test equipment,** *Proc. Soc. exp. Stress Anal.* **12,** 1, 215–226, 1954.

3084. **Jones, R., Testing concrete by ultrasonic-pulse technique,** *Nat. Res. Counc. Highway Res. Bd. Proc. 32nd Ann. Meet.*, 258–275, 1953.

Mechanical Properties of Specific Materials

(See also Revs. 3011, 3034, 3042, 3057, 3060, 3063, 3068, 3074, 3076, 3077, 3079, 3080, 3090)

3085. **Lessells, J. M., Strength and resistance of metals,** New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1954, xiv + 450 pp. $10.

Author discusses practical information about the behavior of metals under stress as it has been developed during recent years. The book is pointed toward the experimental data rather than the theoretical considerations, such as are discussed in the usual books on strength of materials. The subjects treated are the usual ones of the tensile test, effects of overstraining, stress-strain hysteresis, influence of temperatures, hardness, impact, fatigue, mechanical wear, fracture, determination of working stresses. Besides being usable for practical design consideration in many areas, it appears to have possibilities as a text for either advanced undergraduates or beginning graduate students who are interested in the subject of mechanical behavior of metals. The book is easy to read and very well organized. The author points out that this book may be considered as an enlargement and modernization of part II of "Applied elasticity" by S. Timoshenko and J. M. Lessells, Westinghouse Technical Night School Press, 1925.

C. O. Dohrenwend, USA

3086. **Walsh, J. M., and Christian, R. H., Equation of state of metals from shock wave measurements,** *Phys. Rev.* (2) **97,** 6, 1544–1556, Mar. 1955.

Shock waves (pressures 150–500 kilobars) are propagated in metal bars using high explosives. It is assumed that, at these pressures, an equation of state of a fluid type holds, implying a functional relationship between pressure, density, and temperature which the paper determines.

Shock velocity and a further velocity (effectively the material velocity) are measured and the associated Hugoniot curves obtained. Temperatures and isotherms are plotted and appear to give satisfactory extension of static loading results at lower pressures [Bridgeman, AMR 3, Rev. 488].

R. Hetherington, England

3087. **Sinnott, R. J., Rohrig, I. A., Freeman, J. W., and Rush, A. I., Carbon-molybdenum steel steam pipe after 100,000 hours of service,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-73, 16 pp.

Carbon-molybdenum steam pipe, carefully measured for service creep during 100,000 hr of operation at 900 F, was subjected to laboratory examination after removal from service. The purpose was to check calculated service creep rates, assess creep damage, and to compare long-time performance prediction based on short-time laboratory data. Remarkable correlation was observed between calculated service creep rates and those established by subsequent laboratory creep testing. Full agreement

with average values used by the Subgroup on Allowable Stresses for Ferrous Materials of the ASME Boiler Code Committee in setting allowable stresses for this material was established for both creep and stress-rupture properties.

From authors' summary

3088. Kattus, J. R., Properties of cast iron at elevated temperatures, a progress report, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-162, 12 pp.

This investigation is intended to determine the load-carrying ability of cast iron in the temperature range 700 to 1000 F. Screening tests, stress-rupture, and creep tests, and thermal-shock tests are to be carried out. Report covers a literature survey and screening tests on 12 commercial irons to determine their resistance to softening at elevated temperatures. These tests showed good correlation between alloy content and resistance to softening, but the literature survey showed only partial correlation between creep and stress rupture and other elevated temperature properties. Based upon the results of the literature survey and screening tests, a selection of eight irons for stress rupture and creep testing was made. From author's summary

Mechanics of Forming and Cutting

3089. Chao, B. T., and Trigger, K. J., Temperature distribution at the tool-chip interface in metal cutting, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-115, 26 pp.

Authors present a new method of evaluation of the tool chip interface temperatures and the application of their method to the problem of tool wear.

The method, iterative by nature, is based on a revised assumption of heat flux distribution, namely, nonuniform heat and temperature profile, at the interface. The first step of the method requires that all the heat liberated at the interface be transferred into the chip. The heat distribution is assumed uniform at this point and, by means of Yaeger's procedure for moving heat sources, the local temperature is calculated. The temperature distribution so obtained is then assumed coexistent on the top surface of the tool over the region of contact, and the heat flux determined. The latter is then deducted from the total, uniformly distributed interface heat. The difference gives a new (second approximation) heat flux distribution over the chip surface. This again yields a more accurate interface temperature distribution. A third or fourth step is sufficiently accurate in most cases. To determine the heat flux at the top surface of the tool with a given temperature distribution, authors have devised a new approach in which they use the diameter of a point heat source and combine it with some concepts used in the relaxation method.

The results are shown in diagrams. The detailed discussion of the consequences of nonuniform temperature distribution follows the presentation of the analytical method. The conclusions are that, due to the nonuniformity of heat distribution, heat is being conducted from the tool into the chip over a small region close to the cutting edge and that the thermal conductivity of the tool material has only a minor influence on the mean cutting temperature. The temperature distribution is more significant as far as a mean cutting temperature is concerned. Moreover, there is a relatively detailed discussion of the role which the temperature distribution plays in the formation of the cratering wear of the tool.

In conclusion it can be said that the paper represents a valuable contribution to metal-cutting research. The ideas are clearly stated and the new incisive approach will enhance further investigation. A. O. Schmidt, USA

3090. Barz, E., Research on rotational saws used for cutting wood (in German), *Werkstattstech. Maschinenb.* **44**, 5, 228–233, May 1954.

3091. Birebent, A., and Mamillan, M., Study of a jaw crusher (in French), *Ann. Inst. tech. Bât. Trav. publics* no. 82, 965–984, Oct. 1954.

Authors report tests made on stone crusher using various jaw designs and kinds of material to be crushed. With curved, instead of flat jaws: output increases, fine particle size percentage and energy per ton decrease. Using smooth instead of serrated jaw surface: output increases 50%, energy consumed decreases 25% per ton, particle size and fragment form are not affected by jaw's surface condition. If average displacement of movable jaw is increased: fine particle size percentage decreases, crushed material shape improves, output decreases. Fixed jaw inclination has no effect on size distribution and form of fragments; vertical location improves output slightly. With high breaking strength rocks, fragments are less cubical; output, energy consumed, and particle size increase; percentage of fine particle size decreases.

Paper describes in detail the method of grading crushed stone, machine and method of testing, and gives complete data of results. It is a well-prepared report.

M. Martellotti, USA

3092. Sasaki, T., Okamura, K., Matsuda, Y., and Moriyama, H., Research on the cutting performance of fine-grain abrasive stone (in Japanese), *Trans. Japan Soc. mech. Engrs.* **20**, 98, 648–653, 1954.

In many cases, the cutting performance of fine-grain abrasive stone is estimated by testing the bond hardness, but frequently different cutting performances were found for the abrasive stones of the same bond hardness. In order to test the cutting performance of abrasive stone, a special testing apparatus by which stone wear, stock removal, and cutting force can be measured was designed.

The testing results of cutting performance obtained with this testing apparatus were compared to the results of superfinishing performance with same abrasive stone under the most suitable working conditions, and it is shown that this testing apparatus is effective in investigating the cutting performance of the fine-grain abrasive stone. From authors' summary

Hydraulics; Cavitation; Transport

(See also Revs. 3103, 3108, 3109, 3127)

3093. Ostrovskiĭ, A. I., Tracing of water surface curves in circular pipes (in Russian), *Gidrotekh. i Melior.* **7**, 3, 44–51, Mar. 1955.

Routine methods of backwater computation fail in the upper portion of circular pipe; possible alternate depths confuse approximate solutions. Author uses direct integration and expresses all geometric elements of a section as ratios to the pipe diameter. A table of ratios and their functions simplifies computations and also gives the depths of normal and critical flow. Thirty various cases are tabulated. S. Kolupaila, USA

3094. **Khovanskiĭ, G. S., Transparent nomogram for the design of partly filled circular pipes** (in Russian), *Gidrotekh. Stroit.* 24, 2, p. 48, 1955.

Nomogram consist of 2 parts: (1) a grid representing diameter, discharge, roughness coefficient, and hydraulic radius; (2) a superposed sliding scale with slope, velocity, and the depth ratio to diameter. For given discharge and slope, a depth ratio can be read directly to 0.01. S. Kolupaila, USA

3095. **Fortier, A., Damping out the rotation and head losses of gyratory flows in straight pipelines of circular section** (in French), *Houille blanche* **9**, no. B, 670–675, Nov. 1954.

In the gyratory flow in a straight pipeline of circular section with radius r_0, the velocity at any point M at the distance r from the pipe axis is supposed to lie in a plane perpendicular to the radius r. The velocity V has two components: V_x in the direction of the x-axis and V_T in the circular direction. Let θ_0 be the angle of V to V_x near the pipe wall. Author has measured the ratio V_T/V_x and plotted it against r/r_0. He finds that for $\theta_0 > 25°$ the fluid rotates as a solid mass in the central part of the pipe and as a vortex near the pipe wall. For $\theta_0 < 10°$ the whole mass of water rotates as a solid mass. He then studies the variation of the shear stresses τ near the pipe wall and finds that if $z = \tan \theta$, z varies like $z = z_0e^{-\lambda x'}$ with $x' = x/2r_0$ and λ = friction factor in a straight pipe with no rotation. He also studies the head loss and finds that a friction factor λ' can be introduced so that $\lambda' = \lambda[1 + (3\theta_0^2/2)]$ for small values of θ. The author believes these formulas to be valid for values of the Reynolds number larger than 500,000. C. Jaeger, England

3096. **Shaĭmanovskiĭ, I. M., Computation of normal and critical depths in narrow trapezoidal channels** (in Russian), *Gidrotekh. Stroit.* **24**, 2, 42–43, 1955.

A direct solution is offered for a trapezoidal channel within ±3% accuracy when bottom width is less than five times the water depth. Starting with an equilateral triangular section, formulas are derived for a normal and a critical depth, valid for any exponential velocity formula. S. Kolupaila, USA

3097. **Mottard, E. J., and Loposer, J. D., Average skin-friction drag coefficients from tank tests of a parabolic body of revolution (NACA RM-10)**, *NACA Rep.* 1161, 7 pp., 1954.

Average skin-friction drag coefficients were obtained from boundary-layer total-pressure measurements on a parabolic body of revolution (NACA RM-10, basic fineness ratio 15) in water at Reynolds numbers from 4.4×10^6 to 70×10^6. The tests were made in the Langley tank No. 1 with the body sting-mounted at a depth of two maximum body diameters. The arithmetic mean of three drag measurements taken around the body was in good agreement with flat-plate results, but, apparently because of the slight surface wave caused by the body, the distribution of the boundary layer around the body was not uniform over part of the Reynolds number range. From authors' summary

3098. **Blaisdell, F. W., and Donnelly, C. A., The box inlet drop spillway and its outlet**, *Proc. Amer. Soc. civ. Engrs.* **80**, Separ. 534, 41 pp., Nov. 1954.

Paper reports model experiments made to determine the free flow capacity and the effect of submergence on flow over box inlet drop spillways and describes the development of an outlet for the spillway. For the use of the designer, data are presented for the determination of both the free flow capacity and the hydraulic proportions of the outlet structure. Design data to determine the effect of submergence on flow over the spillway are too voluminous to include in this paper. From authors' summary

3099. **Minnesota International Hydraulics Convention Proceedings, Part IV. Air entrainment by flowing water,** Inter. Assn. Hydr. Res., Hydraulics Div., Amer. Soc. civ. Engrs.; Univ. Minn., Minneapolis, Minn., 403–533, Sept. 1953.

The usual relationships do not apply to the flow of air-water mixtures. This group of twelve papers deals with problems encountered in instrumentation, analysis, and design. Results of studies at several laboratories and on prototype structures on the natural entrainment resulting from high-velocity flow are presented. Mean air concentration is found to increase with distance from the bottom, and velocity to be higher than for non-aerated flow. Occurrence in relation to boundary layer is discussed. Advantages are shown for the use of air-entraining baffles in stilling pools, and a design procedure is suggested based on experimental studies. The behavior of a jet falling freely into still water is compared with the submerged jet.

In closed conduit flow, volumes entrained in vertical shafts are measured and factors affecting flow are indicated. Air demand of gated outlet works is treated theoretically and comparison made between results of prototype and model studies. A definite reduction in cavitation pitting with small amounts of entrained air is shown from both laboratory and field tests.

W. DeLapp, USA

3100. **Croes, G. A., and Schwarz, N., Dimensionally scaled experiments and the theories on the water-drive process**, *J. Petr. Technol.* **7**, 3, 35–42, Mar. 1955.

Paper reports the results of a series of model displacement experiments carried out for measuring the efficiency of the water-drive process. This series forms a continuation and extension of that described by Engelberts and Klinkenberg. Detailed information has been obtained on the influence of the oil/water viscosity ratio. The results are represented in the form of a diagram from which both the oil recovery and the water/oil ratio can be easily read off as a function of the total production (oil plus water) for all values of the viscosity ratio M between 1 and 500.

These results are viewed in the light of the two existing theories on water flooding, viz., that of Buckley and Leverett and that of Dietz.

It is shown that if the Buckley-Leverett theory applies, the relation between the relative permeability ratio and saturation, which plays a major role in this theory, can be calculated with a high degree of accuracy from the results of the model experiments.

Dietz's theory is found to be in agreement with the experimental results in a certain range of circumstances. A discussion of the physical background of the Buckley-Leverett and Deitz theories makes it clear why the latter fails to agree with some of the experimental results. From authors' summary

Incompressible Flow: Laminar; Viscous

(See also Revs. 2957, 2960, 3093, 3095, 3097, 3128, 3131, 3143, 3166, 3185, 3204, 3205, 3239, 3240, 3250)

3101. **Woods, L. C., Unsteady plane flow past curved obstacles with infinite wakes**, *Proc. roy. Soc. Lond.* (*A*) 229, 1177, 152–180, Apr. 1955.

Previous work by the author [title source, (*A*), 227, 367, 1955] on steady flow about obstacles with infinite wakes is

now extended to unsteady flow for the case when the velocities and displacements of the unsteady perturbations about the mean steady motion are small. To determine the fluctuating vorticity on the two separation streamlines an integral equation is set up and solved by the author's iteration process. Unsteady Helmholtz flow is given detailed attention. A number of aerodynamic applications are considered, including the impulsive motion of a flat plate and the flutter of a stalled airfoil.

G. Temple, England

3102. Dolidze, D. E., Uniqueness of solution of fundamental boundary-value problem for incompressible viscous fluid (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **96**, 3, 437–439, May 1954.

Purely theoretical, but conditions established on the velocity, space derivatives of velocity, and the pressure at infinity will be useful in order to define functions for the velocity and pressure.

M. Kataoka, Japan

3103. Dean, W. R., Note on the motion of an infinite cylinder in rotating viscous liquid, *Quart. J. Mech. appl. Math.* **7**, part 3, 257–262, Sept. 1954.

It is shown that the two-dimensional motion of an infinite rigid cylinder in a viscous liquid relative to the liquid is unaltered when a uniform rotation is imposed on the whole system. This is an extension of Taylor's result [*Proc. roy. Soc.* (*A*) **93**, 99–113, 1916] for an inviscid liquid.

H. G. Lew, USA

3104. Petukhov, I. V., Inertialess laminar flow of a viscous gas in plane channels (in Russian), *Prikl. Mat. Mekh.* **18**, 4, 385–398, July/Aug. 1954.

Paper treats in a quite general way the solution of the equations of viscous, inertialess gas flow where the physical parameters (viscosity, specific heat, and heat-transfer coefficient) are functions of temperature. Some mathematically convenient specific calculations are given. The tone of the paper is largely academic.

R. A. Burton, USA

3105. Henrici, P., On rotational viscous flow through a tube, *ZAMP* **5**, 6, 511–516, 1954.

Asymptotic approximations are obtained for the eigenvalues arising in the study of the decay of a rotationally symmetric, small swirl superposed on Poiseuille flow in a circular pipe. A method for calculating the low eigenvalues is also given. The results represent an improvement over the approximations to the eigenvalues given by Collatz and Görtler [AMR **8**, Rev. 1057]. Author is apparently unaware that the same method of deriving an asymptotic approximation was previously used by Talbot [AMR 7, Rev. 2900] who, however, gives only the first two terms of the asymptotic series, compared with the four terms given by present author. The improvement of the numerical values due to the inclusion of the additional terms is very small.

G. W. Morgan, USA

3106. Inui, T., and Toba, K., The steady and slow motion of viscous fluid past a prolate spheroid, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 233–238.

A series solution is found for the slow, viscous flow past a prolate spheroid. Authors give numerical values for the leading coefficients of the series in the particular case of a spheroid with fineness ratio 2.4 at a Reynolds number of 3.4, but express reservations about their accuracy. The drag of the spheroid is slightly greater than twice that of a sphere of the same diameter; the corresponding ratio of surface areas is 1.7.

Paper makes a valuable addition to the available solutions for slow motions according to the Oseen approximation.

P. R. Owen, England

3107. Marchetti, L., On the motion of a rigid body in potential flow (in Italian), *Atti. Accad. naz. Lincei, R. C. Sci. Fis. Mat. Nat.* (8) **15**, 274–278, 1953.

The author points out that, in the class of steady flows having the same density field, Kelvin's theorems of minimum energy and uniqueness of potential flow hold. [The reviewer regards this fact as well known and has included a proof of a variant of the latter theorem in §37 of "The kinematics of vorticity," Indiana Univ. Press, Bloomington, 1954; AMR **7**, Rev. 3936.] The author suggests that one could solve the problem of potential flow by this means: using measured or otherwise conjectured values of the density, set up by the velocity potential as a linear combination of known solutions of the potential equation with this given density, then determine the coefficients so as to minimize the kinetic energy.

C. Truesdell, USA

3108. Mitchner, M., An approximate solution to the Navier-Stokes equations (Note), *Quart. appl. Math.* **12**, 4, 401–404, Jan. 1955.

Note shows how a new approximate solution of the Navier-Stokes equations may be constructed from any given exact solution having a certain specified form.

From author's summary

3109. Panetti, M., Study Center for fluid dynamics: its activity during the year 1954 (in Italian), *Ric. sci.* **25**, 1, 29–33, Jan. 1955.

Compressible Flow, Gas Dynamics

(See also Revs. 2960, 3109, 3132, 3139, 3142, 3147, 3148, 3155, 3157, 3164, 3172, 3185, 3201)

3110. Rudinger, G., Wave diagrams for nonsteady flow in ducts, Toronto, New York, London, D. van Nostrand, Inc., 1955, xi + 278 pp. $6.

An extended description of method of characteristics for one-dimensional flow is cast in sufficient generality to include treatment of variable duct width, removal of fluid through walls, variable entropy, heat addition, shock fronts, contact discontinuities, flame fronts, etc. Three chapters are devoted to introduction and a thorough development of general methods for handling typical computational situations. Two chapters treat boundaries, discontinuities, and interaction of discontinuities. Two chapters are devoted to practical suggestions on the technique of construction of wave diagrams, or characteristic nets in the *xt*-plane, and to detailed accounts of several complete numerical examples. Tables of shock properties are included for $\gamma = 1.4$, 5/3, and 4/3. A bibliography of 96 papers includes references to heat engines, shock tubes, pulse starting of wind tunnels, and other examples of unsteady flow in ducts.

The procedure described is hand computation accompanied by graphical work to visualize the flow. Simplifications and short

cuts, such as replacement ducts of continuously varying width by ducts with stepped walls, are discussed. Care is taken to stress the arbitrariness or crudeness of the treatment of phenomena at present incompletely or inadequately understood, such as heat addition and flame fronts.

The exposition is pitched to keep demands on the reader's mathematical training at the lowest possible level, which is generally, but not invariably, desirable. Reviewer believes, for example, that the author's derivation of characteristic conditions will appear more mysterious and difficult for newcomers to this field to understand than the common development in terms of the propagation of discontinuities which can be presented very simply and easily. Furthermore, whether the book is intended for novices or more experienced readers, there is a regrettable absence of experimental material, such as the photographic records of shock-tube phenomena and comparisons of theory and experiment presented in the work of I. I. Glass and G. N. Patterson [AMR **8**, Rev. 169], to which the bibliography refers.

J. H. Giese, USA

3111. Ward, G. N., The drag of source distributions in linearized supersonic flow, *Coll. Aero. Cranfield Rep.* 88, 14 pp., Feb. 1955.

Starting with a general expression for the drag due to supersonic sources within a volume, author considers, first, thin (winglike) and then, slender bodies. In both cases the boundary condition at the surface can be satisfied by surface distributions of sources of strength proportional to the surface slope. The formula obtained for the drag of thin wings resembles Lighthill's result for a special class of plane wings [AMR **2**, Rev. 1163]. The formula for the drag of slender bodies is a generalization of Lighthill's result for bodies of revolution with discontinuities of meridian section [AMR **3**, Rev. 532].

The minimum drag of a slender fuselage with attached, prescribed, thin wings is considered next. It is shown that the problem can be reduced to that of minimizing the drag of a certain fictitious slender body whose area distribution (along the stream direction) is the sum of the real area distribution sought $S(z)$ and a distribution $A(z)$ of the given wing volume according to a prescription given here. The prescription is simply that every volume element of the wing is distributed (nonuniformly) over the part of the longitudinal body (z) axis intercepted between its forward and rearward Mach cones. Thus the wing volume is distributed over that part of the axis intercepted between the Mach cones from the wing tips. It appears, therefore, that the minimum drag of the wing-body combination at no lift is achieved when $S(z) + A(z)$ is distributed in the shape of a minimum-drag slender body, such as has been worked out by several authors. The total drag is then not equal to the drag of this fictitious slender body but can be computed in a straightforward manner. The result is obviously important.

W. R. Sears, USA

3112. Kaplan, C., On the small-disturbance iteration method for the flow of a compressible fluid with application to a parabolic cylinder, *NACA TN* 3318, 36 pp., Jan. 1955.

A neat procedure is given for calculating the successive terms in Prandtl-Busemann (P-B) expansions for two-dimensional steady compressible subsonic flow. P-B expansion proceeds in powers of a small dimensionless parameter usually identified with the body-thickness ratio. Author applies method formally to flow past a parabolic cylinder for which no thickness parameter can be defined. Identification of expansion parameter with M_∞ instead produces Janzen-Rayleigh expansion. Reviewer is not surprised. No clear discussion of significance of the approximations is presented. Lastly, an expansion of the parabolic cylinder solution valid for downstream is carried out to third order.

J. D. Cole, USA

3113. Gilbarg, D., and Serrin, J., Uniqueness of axially symmetric subsonic flow past a finite body, *J. rat. Mech. Analysis* **4**, 1, 169–175, 1955.

The uniqueness of steady irrotational subsonic flow past an axial symmetric body is established by the use of a Pragmén-Lindelöf type of theorem. The main use of this theorem is to establish rigorously that $\psi - \frac{1}{2} Q_0 y^2 \rightarrow 0$ at infinity, where ψ is the stream function and Q_0 is the free stream mass flow. The uniqueness theorem follows by an argument parallel to one already given [AMR **6**, Rev. 3486] for plane flows.

The work is of interest to theoretical workers rather than engineers.

L. C. Woods, Australia

3114. Kaplan, C., The small-disturbance method for flow of a compressible fluid with velocity potential and stream function as independent variables, *NACA TN* 3229, 18 pp., Aug. 1954.

Author recently suggested that usual small-disturbance procedure fails to converge for incompressible flow past sinusoidal wall, and proposed an alternative solution using velocity potential and stream function as independent variables [AMR **7**, Rev. 2208]. Present paper gives corresponding analysis for small disturbances of compressible flow. Differential equations for first three iteration steps are cast into complex-vector form, and particular integrals found. As example, solution is carried out for sinusoidal wall in subsonic flow.

M. D. Van Dyke, USA

3115. Lidov, M. L., Exact solutions of equations for one-dimensional uniform motion of gases taking into account Newtonian gravitational forces (in Russian), *Doklađi Akad. Nauk SSSR (N.S.)* **97**, 3, 409–410, July 1954.

By superposing a weak two-dimensional perturbation on a plane shock front in an inviscid nonconducting gas of rather general thermodynamic properties, author investigates conditions under which the shock front is unstable to small disturbances (both sound pulses and vorticity sheets) and finds some (P-V) curves and shock strength ranges which may arise in partly dissociated high-temperature gases where instability may be expected.

L. Trilling, USA

3116. Zhukov, A. I., On a family of exact solutions of the equations of hydrodynamics (in Russian), *Doklađi Akad. Nauk SSSR (N.S.)* **97**, 985–986, 1954.

Author constructs solutions of the equations of steady axisymmetric inviscid compressible flow that involve an arbitrary function and solutions of a system of three first-order ordinary differential equations.

J. H. Giese, USA

3117. Syrovatskiĭ, S. I., Instability of tangential discontinuities in a compressible medium (in Russian), *Zh. eksp. teor. Fiz.* **27**, 121–123, 1954.

Let the half-space $x > 0$ (<0) be filled with fluid moving with constant velocity v_0 (0) parallel to the y-axis. By considering general exponential plane-wave solutions of the linearized system of partial differential equations for time-dependent perturbations subject to appropriate boundary conditions at the perturbed dis-

continuity surface, author concludes that for all v_0 the motion is unstable. This contradicts L. D. Landau's earlier conclusion [*C. R. (Doklady) Acad. Sci. URSS (N.S.)* **44,** 139–141, 1944] obtained by use of plane waves of very special form: that for large enough v_0 the motion is stable. J. H. Giese, USA

3118. Savin, R. C., Application of the generalized shock-expansion method to inclined bodies of revolution traveling at high supersonic airspeeds, *NACA TN* 3349, 71 pp., Apr. 1955.

Subject to the limitation that the hypersonic similarity parameter K (ratio of stream Mach number to body-fineness ratio) exceeds unity, the straightforward use of the (plane) Prandtl-Meyer expansion is described for calculating the flow about lifting bodies of revolution. The main difficulty is that of describing the initially conical flow at the vertex, as the Mach numbers and flow angles of interest are beyond the range of the M.I.T. tables [AMR **3,** Rev. 935]. A solution of the problem is found under the justifiable assumptions that the shock is circular and lies near the body, though not concentric with it. For the special case of slender bodies, explicit expressions for the surface conditions are found.

Agreement with experimental measurements at Mach numbers of 3 to 5 and angles of attack up to 15° for several cones and ogives is good in all respects, with the agreement decreasing as K drops toward 1.

This is the logical extension of a previous application [by Eggers and Savin, AMR **5,** Rev. 1795] of the shock-expansion method to nonlifting bodies of revolution at high Mach number.

S. H. Maslen, USA

3119. Freeman, N. C., A theory of the stability of plane shock waves, *Proc. roy. Soc. Lond. (A)* **228,** 1174, 341–362, Mar. 1955.

The stability of form of a plane shock, obtained when a "corrugated" piston is moved impulsively from rest with constant velocity, is investigated mathematically. Linearization of the problem is accomplished by assuming the corrugations to be small. The solution is built up by methods of Fourier analysis from "cone field" solutions of the analogous wedge-shaped piston problem, solved by methods due to Lighthill. The plane shock is shown to be stable, perturbations from plane decaying with time in an oscillatory manner like $t^{-3/2}$ for large ta_1/λ (where a_1 is the velocity of sound behind the shock and λ the wave length of the corrugations). The stability, measured by the amplitude of this oscillation after the shock has traversed a given distance, decreases both as the shock Mach number increases above and decreases below the value 1.14. Shocks of this strength exhibit strongest stability.

Asymptotic forms for large time are given for both the shock shape and pressure distribution for shocks of moderate strength. A more complicated asymptotic form for the shock shape holds at large Mach numbers, which in the limiting case of infinite Mach number gives the result that the perturbations of shape decay like $t^{-1/2}$ only. Complete solutions are obtained for weak shock in terms of Bessel functions.

From author's summary by A. R. Mitchell, Scotland

3120. Thomas, T. Y., A remark on detached shocks, *Proc. nat. Acad. Sci. Wash.* **40,** 1002–1004, 1954.

Let R be the radius of a sphere or circular cylinder in a supersonic flow without viscosity or thermal conductivity, let φ be the distance from the obstacle to the vertex of the shock, and let κ be the curvature of the shock at its vertex. By dimensional analysis and similarity arguments it is shown that φ/R and κR depend only on the free-stream Mach number and the ratio of specific heats. It should be remarked that these are merely special cases of the well-known criterion for similarity of nonviscous flows about geometrically similar objects. J. H. Giese, USA

3121. Cabannes, H., Influence of accelerations on the curvature of shock waves (in French), *Rech. aéro.* no. 39, 3–13, 1954.

The flow due to the motion through the air of a body of revolution with a pointed nose, along its axis at a supersonic speed varying with time, in the case when the shock wave is attached, is treated by writing down the equations of motion in spherical polar coordinates r, θ with the nose as origin, and expanding in powers of r to obtain information on conditions near the nose. The terms independent of r in the velocity and pressure fields are those which appear in the steady flow about a cone, and have been extensively tabulated by Kopal ["Tables of supersonic flow around cones," Dept. Elec. Engng., Mass. Inst. Tech., Cambridge, Mass., 1947]. The terms in r consist of one term proportional to the curvature of the meridian section of the body at the nose, and another proportional to the instantaneous acceleration of the body. Otherwise they depend only on the nose semi-angle and the instantaneous Mach number of the body's motion. The terms proportional to nose curvature have been found previously [Cabannes, AMR **5,** Rev. 2421; also *Rech. aéro.* no. 27, 7–16, 1952; Lin and Shen, AMR **5,** Rev. 1467]. The terms proportional to acceleration are approximately found here, by assuming their gradient with respect to θ to be uniform and equal to its value at the body surface. On this approximation, author derives an expression for the curvature of the shock wave which is a linear combination of the nose curvature of the body and the acceleration, with the coefficients of both depending on Mach number and nose semi-angle. A rough order of magnitude of the new term (due to acceleration) is a quarter of the acceleration divided by the square of the velocity of sound. (The corresponding radius of curvature would be eight times the distance in which the given acceleration would bring a body from rest to the speed of sound.)

The analogous problem in two-dimensional supersonic flow is also treated, and here exact solutions are found by analytical means. The effect of acceleration on shock wave curvature appears to be less than in the axisymmetrical case.

M. J. Lighthill, England

3122. Beckwith, I. E., and Moore, J. A., An accurate and rapid method for the design of supersonic nozzles, *NACA TN* 3322, 57 pp., Feb. 1955.

The method of characteristics is applied to obtain tabulated flow parameters enabling rapid design of a nozzle contour to develop radial supersonic flow from uniform parallel sonic flow. Use of Foelsch equations is recommended by authors to design remainder of contour to produce uniform parallel supersonic flow. Report deals with two-dimensional flow only, with ratio of specific heats of 1.4, and no actual nozzle results are mentioned.

W. Rice, USA

3123. Murasaki, T., On sonic and high subsonic free jet with staggered nozzle exit (in Japanese), *Rep. Inst. Sci. Technol. Tokyo* **8,** 5, 205–208, Oct. 1954.

The field of a free jet, outside pressure of which is not lower than a critical value, is decided by using Tricomi's equation.

It is natural that, when a nozzle is staggered, the deviation of the jet will be a function of the length of stagger. As is usually done, a calculation is made in a hodograph plane, and a singularity which appears at infinity in the physical plane is treated by introducing Fourier expansion of the boundary condition on vertical axis which has a discontinuity at the origin of hodograph plane. From author's summary

3124. Weir, A., Jr., York, J. L., and Morrison, R. B., Two- and three-dimensional flow of air through square-edged sonic orifices, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-112, 17 pp.

In this investigation, the two-dimensional flow of air through rectangular, and the three-dimensional axisymmetrical flow of air through circular, square-edged sonic orifices were examined under pressure ratios ranging from 1.894 to 42.0 (upstream stagnation pressure/downstream static pressure). Mass flow measurements were made using a primary metering system, rather than another orifice or nozzle, and optical techniques were used to obtain pictures of the flow upstream, within the thickness of the orifice plate, and downstream of the orifice. Evidence is presented which indicates that square-edged sonic orifices can be treated as sonic nozzles by utilizing the concept that the air "turning the corner" of the orifice plate, in effect, makes its own nozzle. It is believed that this interpretation of experimental observations is in full agreement with established principles of aero- and thermodynamics. From authors' summary

3125. Fleddermann, R. G., and Stancil, R. T., Wedge pressure coefficients in transonic flow by hydraulic analogy, *J. aero. Sci.* 22, 4, 271–273, Apr. 1955.

Note in Readers' Forum.

3126. Marchal, R., Conditions for the appearance of shock waves in steady flows, *J. aero. Sci.* 22, 4, 275–276, Apr. 1955.

Note in Readers' Forum.

Wave Motion in Fluids

(See also Rev. 3085)

3127. Dmitriev, A. A., Propagation of small-amplitude two-dimensional waves over a submerged wall (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **97,** 6, 981–984, Aug. 1954.

Completing author's former calculations, the form of the free surface is investigated when waves are partially reflected at a submerged wall, and it is shown that the pressure field contains three types of oscillations. W. Wuest, Germany

3128. Ursell, F., Water waves generated by oscillating bodies, *Quart. J. Mech. appl. Math.* **7,** part 4, 427–437, Dec. 1954.

In a previous paper [AMR 7, Rev. 1030] the potential of a circular cylinder oscillating vertically in a liquid near a free surface was derived for the case of large diameter-wave-length ratio, in the form of an iterative solution of an integral equation of the second kind. In present paper, the same integral equation is solved more simply, but only approximately.

An essential disagreement between the results of these papers and other approximate theories is that the latter predict the occurrence of an infinite number of small minima in the ratio of wave amplitude to heave amplitude expressed as a function of frequency. It is shown that this discrepancy is due to the implicit neglect of the contributions of a distribution of oscillating doublets. These yield the result that short waves generated on one side of a body cannot pass under the body and, therefore, cannot contribute to the wave amplitude on the other side. This intuitively obvious shielding effect was not obtained by earlier approximate methods. L. Landweber, USA

3129. Karreman, G., On the velocity of propagation of pressure waves in an incompressible viscous fluid enclosed in a tube with an elastomeric wall, *Bull. math. Biophys.* **16,** 103–109, 1954.

Rashevsky [title source **7,** 25–33, 1945] presented an approximate analysis for pressure waves in liquid-filled, elastic tubes by assuming that a deformation of the tube which is periodic along the tube axis may be represented by a square wave function (i.e., the deformation is uniform over a distance equal to one half of the wave length). The present author follows Rashevsky to treat the same problem when the tube wall is elastomeric, and obtains an expression for the velocity of wave propagation in terms of the parameters describing the tube and the density and viscosity of the liquid. Reviewer notes that the effect of viscosity is taken into account so roughly that its influence on the wave velocity as predicted by the analysis is not even qualitatively correct [see Morgan and Kiely, AMR **8,** Rev. 1718].

G. W. Morgan, USA

3130. Castanho, J. P., Wave studies of seaports with aid of model studies (in Portuguese), *Minist. Obras Públ. Lab. Engen. civ. Lisboa Pub.* 39, 49 pp., 1953.

Turbulence, Boundary Layer, etc.

(See also Revs. 2960, 2965, 3172, 3185, 3226, 3257, 3258)

3131. Rouleau, W. T., and Osterle, J. F., The application of finite difference methods to boundary-layer type flows, *J. aero. Sci.* 22, 4, 249–254, Apr. 1955.

Finite difference techniques are applied to the problem of slightly viscous, incompressible, constant pressure flow confined by boundaries (solid or porous) on which the "no-slip" condition prevails. A "stepwise" method of solution is found to be unstable on the boundaries. An always stable "implicit" form of the difference equations is developed, and methods of solution by relaxation or iteration techniques are presented. Both stepwise and implicit procedures are suitable for programming on digital computers. Illustrative examples include the problems of the boundary layer over a flat plate with suction and the two-dimensional jet issuing adjacent to a plate into a moving stream.

From authors' summary by G. M. Low, USA

3132. Probstein, R. F., Interacting hypersonic laminar boundary layer flow over a cone, *AF Tech. Rep.* 2798/1, 26 pp., 9 figs., Mar. 1955.

Author considers a laminar hypersonic boundary layer on an unyawed cone sufficiently far from the nose so that the interaction between the shock and boundary layer is weak. Essentially it is an extension of previous work [Princeton Univ. Aero. Engng. Lab. Rep. 195, April 20, 1952, and an unpublished 1953 report]. While the detailed results of the present report will be of interest to workers in the field, the development is too sketchy to be easily followed without consulting the references.

W. Squire, USA

3133. Coles, D., The problem of the turbulent boundary layer, ***ZAMP*** **5, 3, 181–203, 1954.**

A critical review is made of the available experimental data relating to the mean velocity and skin friction in two-dimensional incompressible flow past smooth flat plates at large Reynolds number with zero pressure gradient and without heat transfer and its comparison with the corresponding properties of the ideal boundary layer. It is shown that the uniqueness of the properties of the laminar boundary layer can be examined, since theoretical solutions exist which have been verified experimentally. Due to the lack of an adequate theory of turbulent shear flow, it is stated that the uniqueness question for the turbulent layer is more difficult to settle.

After a brief summary of the experimental investigations into the structure of turbulent shear flows, from which the inadequacy of the mixing length theories is clearly demonstrated, author analyzes the mean properties of the turbulent layer on the basis of physical similarity. By this method the law of the wall and the velocity defect law are deduced together with the laws for the other mean properties of the turbulent boundary flow. As a result of comparison with experiment, where emphasis is placed on the measurements of skin friction using the floating element technique, the values of certain universal constants are determined and the properties of the ideal turbulent boundary layer are tabulated. The fully developed boundary layer is found to be unique, at least within the accuracy of the experimental data.

This study, which is intended to provide a point of departure for compressible boundary layers, is recommended for all workers in this field. G. M. Lilley, England

3134. Sandborn, V. A., and Slogar, R. J., Longitudinal turbulent spectrum survey of boundary layers in adverse pressure gradients, ***NACA TN*** **3453, 40 pp., May 1955.**

Paper reports further results from long-range study of boundary layer in adverse pressure gradient. Previous work was presented by same authors in AMR 8, Rev. 2072. In a low-speed air tunnel, an arbitrary, but fixed, pressure gradient has been set up and as many properties of the boundary layer as possible measured. Reported herein are measurements of spectra of longitudinal velocity component. Various positions, all near the wall at four locations in the direction of flow, were used. Results are presented both in tables and graphs. In short discussion of results, authors indicate trends and show that variations predicted from hypothesis of statistical equilibrium are borne out.

Reviewer believes that real value of paper is not in material as presented but in its use in development of theory of shear flows. W. D. Baines, Canada

3135. Favre, A., Gaviglio, J., and Dumas, R., Apparatus for measurements of time and space correlation (translation of *Rech. aéro.* no. 31, 37–44, Jan.–Feb. 1953), ***NACA TM*** **1371, 20 pp., Apr. 1955.**

Space-time correlation in turbulence is quite important and the first installation to perform such measurements is described in this paper. Besides the more conventional equipment (low-turbulence wind tunnel, two-channel hot-wire anemometer), authors developed a two-channel variable delay by utilizing magnetic tape recorders. The relative delay can be varied by controlling the loop length between the recording and play-back heads. Direct recording on the tape is used in the band 200–2500 cps, and AM modulated 3500 cps carrier is used in the 1–25 cps band, and combination of both in the 25–300 cps band. The correlation between the delayed signals is measured by the "quarter-square" method. The performance of the equipment is checked by comparing power spectra obtained both directly (wave analyzer) and from the measured autocorrelation. S. G. Kovasznay, USA

3136. Favre, A., Gaviglio, J., and Dumas, R., Measurements of turbulent intensity, time correlation, and spectrum in boundary layers (in French), *Publ. sci. tech. Min. Air. France.* no. 296, 243–267, 1955.

Hot-wire measurements were made in a boundary-layer at the same location Ux/ν = 766,000, where the layer can be made either laminar or turbulent by simply varying the background turbulence level in the tunnel. The intensity of u' fluctuations, the time correlation (autocorrelation), and the energy spectrum were measured at several distances from the wall. The penetration of free-stream turbulence into the laminar boundary layer was also explored. S. G. Kovasznay, USA

3137. Shepard, C. E., A self-excited, alternating-current, constant-temperature hot-wire anemometer, ***NACA TN*** **3406, 29 pp., Apr. 1955.**

Anemometer is constructed to study turbojet-engine compressor rotating stall and surge; essentially it consists of an Ni-Fe wire of 25μ, 2.5 mm long, connected to a constant-temperature arrangement according to Ossofsky. After a short survey of the theory of the constant-temperature anemometer, the requirements for stability and prevention of wire burnout are given. A description of the anemometer and of the dynamic and static characteristics is added. An appendix summarizes the relation between air flow and heating current and wire temperature calculations. B. G. van der Hegge Zijnen, Holland

3138. Sato, H., Kobashi, Y., Iuchi, M., Yamamoto, K., and Onda, Y., New equipment for turbulence measurements (in Japanese], *Rep. Inst. Sci. Technol. Tokyo* **8, 6, 271–283, Dec. 1954.**

3139. Reller, J. O., Jr., and Hamaker, F. M., An experimental investigation of the base pressure characteristics of nonlifting bodies of revolution at Mach numbers from 2.73 to 4.98, ***NACA TN*** **3393, 45 pp., Mar. 1955.**

Base pressure characteristics of related nonlifting bodies of revolution are investigated at free-stream Mach numbers from 2.73 to 4.98 and Reynolds numbers from 0.6×10^6 to 8.8×10^6. The basic body shape is a 10-caliber tangent ogive with a cylindrical afterbody. The variation of base pressure coefficient with free-stream Mach number and Reynolds number was determined for laminar-, transitional-, and turbulent-boundary-layer flow. Some effects of body fineness ratio, nose-profile shape, and afterbody shape (boattail) are also included in the investigation.

From authors' summary

3140. Brinich, P. F., Boundary-layer transition at Mach 3.12 with and without single roughness elements, ***NACA TN*** **3267, 41 pp., Dec. 1954.**

Transition on a hollow cylinder aligned with the air stream was studied in a Mach 3.12 wind tunnel at Reynolds numbers from 1×10^5 to 7×10^5 per inch. Transition was observed from surface-temperature distributions and schlieren photographs with and without single roughness elements. Without roughness, the transition Reynolds number varied as the square root of the

stream Reynolds number per inch. The results obtained with roughness followed the trends of Dryden's low-speed correlation. The degree of roughness required was found to be three to seven times as great as for low-speed flows.

From author's summary

Aerodynamics of Flight; Wind Forces

(See also Revs. 3113, 3161, 3162, 3163, 3174, 3176, 3206, 3216)

3141. DeYoung, J., Calculation of span loading for arbitrary plan forms, *J. aero. Sci.* **22,** 3, 208–210, Mar. 1955.

The Weissinger method, which is strictly applicable only to constant angles of sweep, is extended through a different treatment of the integral equation to variable sweep of the quarter-chord line. The computational effort involved is determined by the number of spanwise positions at which the loading is determined and by the number of terms used in the numerical integration of the loading at these positions. An example is worked out for various combinations of these numbers.

A. M. Kuethe, USA

3142. Wright, L. C., Approximate effect of leading-edge thickness, incidence angle, and inlet Mach number on inlet losses for high-solidity cascades of low cambered blades, *NACA TN* 3327, 38 pp., Dec. 1954.

Inlet losses are calculated from purely theoretical considerations, utilizing theorem of fluid momentum, continuity, and conservation of energy, and assuming zero nose pressure. Results, presented in various graphs, indicate possibility of high inlet losses at off-design conditions, and also indicate that large stagger angles should be avoided when wide operating range is required.

C. W. Smith, USA

3143. Ehrich, F. F., Secondary flows in cascades of twisted blades, *J. aero. Sci.* **22,** 1, 51–60, Jan. 1955.

General analysis of the perturbation flow resulting from the passage of a nonuniformly distributed velocity through a model system of cascades has been made. Comparisons with previous theoretical analyses by others and also with some experimental measurements made by the author show that the analysis is useful except when the simple model no longer represents the actual physical situation, as in the regions of viscous flow. The analysis is also limited to small turning angles, to small pressure variations in the direction of the height of the blades, and to incompressible flow.

Y. V. G. Acharya, USA

3144. Ramsen, J. A., and Vaughan, V. L., Jr., Hydrodynamic tares and interference effects for a 12-percent-thick surface-piercing strut and an aspect-ratio-0.25 lifting surface, *NACA TN* 3420, 20 pp., Apr. 1955.

Results are presented from an investigation of the hydrodynamic tares and interferences acting on an NACA 661-012 airfoil-section surface-piercing strut and an aspect-ratio-0.25 modified-flat-plate rectangular lifting surface. The interference of the strut on the lifting surface was negligible except at very shallow depths, where it increased the lift and pitching moment slightly. Strut-tare effects were appreciable only on drag, where section-drag coefficients showed good agreement with data from previous tank and wind-tunnel tests. The surface-intersection drag coefficients were constant above the critical wave speed and showed fairly good agreement with wave-drag theory below the critical speed.

From authors' summary

3145. Haskell, R. N., and Johnson, W. S., Jr., Equations for loading on triangular wings having subsonic leading edges due to various basic antisymmetric twist distributions, *J. aero. Sci.* **22,** 4, 278–280, Apr. 1955.

Note in Readers' Forum.

Using the integral equations presented by Zienkiewicz for the antisymmetric boundary condition, load distributions are found for wings with local incidence proportional to t, t^2, and t^3.

From authors' summary

3146. Kuhn, R. E., and Draper, J. W., An investigation of a wing-propeller configuration employing large-chord plain flaps and large-diameter propellers for low-speed flight and vertical take-off, *NACA TN* 3307, 94 pp., Dec. 1954.

An investigation of the effectiveness of a wing equipped with large-chord plain flaps and auxiliary vanes in rotating the effective thrust vector from two large-diameter propellers to a near vertical attitude for vertical take-off and low-speed flight has been conducted in the Langley 300-mph 7- by 10-foot tunnel. The model consisted of a semispan wing equipped with a 60%-chord and a 30%-chord plain flap. Two large-diameter overlapping propellers, driven by electric motors, were used. The tests covered a range of angle of attack from 0° to 90° and a thrust-coefficient range representative of free-flight velocities from zero to the normal range of cruising velocities.

From authors' summary

3147. Lomax, H., Fuller, F. B., and Sluder, L., Generalized indicial forces on deforming rectangular wings in supersonic flight, *NACA TN* 3286, 74 pp., Nov. 1954.

The velocity potential over a rectangular wing following the sudden imposition (at $t = 0$) of a distortion of the form $x^m y^n$ is calculated by Gardner's method [AMR **4,** Rev. 2124] and expressed in terms of integrals over a "reflected area" analogous to that appearing in Evvard's solution for the steady-flow problem [AMR **4,** Rev. 3310]. The results are applied to the motion of a wing in the form of a uniform plate, and the calculation of the required, generalized forces is discussed. Numerical results are given for distortion polynomials of the first and fifth degrees, respectively, in the chordwise and spanwise directions, Mach numbers of 1.1 and 1.2, and aspect ratio 4. The authors' discussion implies that Gardner's method is superior to that of the reviewer [AMR **7,** Rev. 225] for the problem at hand; while this may be true for indicial motion, as treated by the authors, the reviewer believes that his method probably is more convenient in the treatment of simple harmonic motion and notes the availability of extensive calculations based thereon [J. Brandstatter and H. Mortzschky, Lockheed Aircraft Rep. MAM 245 (April 1, 1954)] and of explicit integrals for wing distortions of polynomial form [AMR **4,** Rev. 3629]. The choice between the two basic types of motion, viz., (A) indicial or (B) simple harmonic, in practical flutter analysis depends, of course, on the method of computation. Classical methods require (B), and it appears that such methods are preferable for digital computers; on the other hand, (A) appears to be preferable for at least some analog computers [AMR **4,** Rev. 1738; but cf. R. H. MacNeal, G. D. McCan and C. H. Wilts, *J. aero. Sci.* **18,** 71–72, 1951].

J. W. Miles, USA

3148. Asaka, S., On the velocity distribution over the surface of a symmetrical aerofoil at high speeds. I., *Nat. Sci. Rep. Ochanomizu Univ.* **4,** 213–226, 1954.

An outline is given of Imai's thin-wing-expansion method.

The method is modified in order to simplify the procedure for making higher-order approximations to the velocity distribution on airfoil surfaces. Application of the theory to a symmetrical circular-arc airfoil is reserved for a later paper.

D. C. Pack, Scotland

3149. Bates, W. R., Static stability of fuselages having a relatively flat cross section, *NACA TN* 3429, 29 pp., Mar. 1955.

Paper supersedes declassified *NACA RM* L9I06a. Author reports results of tests on several high-fineness-ratio fuselages, both with and without attached vertical and horizontal surfaces. Work was carried out in Langley Free-Flight Wind Tunnel. Results include lateral and longitudinal stability of fuselages with both horizontal and vertical major cross-sectional axis. Also included are the effects of attaching to fuselages a vertical movable tail, dorsal and ventral fins, canopies in various positions, horizontal tail, asymmetric fins. Analysis of results and diagrams of flow investigation with streamers indicate that sidewash from relatively flat part of fuselage nose and from tails is the controlling factor in stability.

Reviewer believes paper represents definite contribution in field of stability and control of airframes with relatively flat cross-section shape.

H. L. Bloom, USA

3150. Birman, Joan, The effects of changes in aircraft weight on flight equilibrium, *J. aero. Sci.* 22, 1, 61–62, Jan. 1955.

Note in Readers' Forum.

3151. Covert, E., A particular solution of a nonlinear differential equation which occurs in the dynamics of conservative systems and its application to undamped airplane motion, *J. aero. Sci.* 22, 2, 134–135, Feb. 1955.

Note in Readers' Forum.

3152. Cicala, P., and Miele, A., Brachistocronic maneuvers of a constant mass aircraft in a vertical plane, *J. aero. Sci.* 22, 4, 286–288, Apr. 1955.

Note in Readers' Forum.

3153. Coleman, T. L., Copp, M. R., Walker, W. G., and Engel, J. N., An analysis of accelerations, airspeeds, and gust velocities from three commercial operations of one type of medium-altitude transport airplane, *NACA TN* 3365, 31 pp., Mar. 1955.

Time-history data obtained by the NACA VGH recorder from one model of a four-engine civil-transport airplane during operations on three routes are analyzed to determine the magnitude and frequency of occurrence of gust velocities, gust and maneuver accelerations, and the associated air speeds. Variations of the gusts and gust accelerations with route and flight condition are indicated. Estimates of the over-all gust and gust-load histories for extended operations on one route are obtained by supplementing the data from the NACA VHG recorder with available data from the NACA V-G recorder.

From authors' summary

3154. Just, W., Influence of design parameters and flight data of an airplane upon the lateral stability properties (in German), *Z. Flugwiss.* 2, 10, 259–277. Oct. 1954.

In order to facilitate the direct use of wind-tunnel measurements, the equations for the angles of side slip, roll, and yaw are written in the experimental system of coordinates and subsequently, as usual, brought into dimensionless form. Using linearized small disturbance theory the conditions for lateral stability are given and with their aid an attempt is made to obtain a survey of the effects of the various design parameters on the stability boundaries and the rate of damping. Among others are discussed the effects of span, loading, aspect ratio, taper ratio, twist, dihedral, and angle of sweep of the wing, flap deflections, area, aspect ratio, and moment arm of the vertical tail plane, mass distribution (radii of inertia) on the boundaries of spiral and dutch roll stability. These are related to the damping of spiral and dutch roll motion, and on the oscillation period of the dutch roll. This discussion is mainly qualitative, but it is quantitatively strengthened by numerical calculations for two extreme types of aircraft (geometry about the same as for DC-4 and D 558-2). The considerable difference in lateral stability between conventional transport airplanes with piston engines and propellers, on the one side, and modern high-speed airplanes with sweptback wings and jets, on the other side, is thus clearly emphasized.

As a result of these calculations the boundary curves for spiral and dutch roll stability are plotted in a $C_{L\beta}'$, $C_{N\beta}'$ diagram and discussed in various cases. For a more thoroughgoing study, the angles of side slip, roll, and yaw are given as functions of dimensionless time in two cases, one case corresponding to cruising of the large transport aircraft at low altitude, the other case corresponding to landing of the high-speed aircraft.

Of interest for the design engineer are the statistical data given at the end; these data concern the relative area and the relative moment arm of the vertical tail plane, the directional stability derivative $C_{N\beta}$, and the contribution of the vertical tail plane to the directional stability (at zero lift, without propeller and jet effects) for 41 airplanes with piston engines (11 light planes with one engine, 4 fighters with one engine, 8 airplanes with two and 18 with four engines), for 24 jet-propelled airplanes (14 with one engine (8 of them with sweptback wings), 8 with two or four engines, 2 with six engines), and for 5 supersonic airplanes.

H. Behrbohm, Sweden

3155. Walker, K., Jr., Rolling characteristics of narrow-delta cruciform wings with canard-delta or trailing-edge ailerons, *Douglas Aircr. Co. Rep.* SM-18309, 24 pp., Mar. 1954.

Continuation of author's earlier work on wide-delta cruciform wings [AMR 8, Rev. 471] is reported. Using linearized supersonic conical flow theory, rolling moment due to control surface deflection is calculated as a function of relative control surface chord, apex angle, and Mach number for the alternative control surfaces. Damping-in-roll derivatives according to Bleviss and Ribner for both wide and narrow delta cruciform wings are added.

Interference is considered between horizontal and vertical wing panels, the former being provided with ailerons. As theory is linear, effect of vertical ailerons may be found by superposition. Analytical results are restricted to the case where flow in the right-hand half plane is independent of flow in the left-hand half plane.

Author concludes that roll characteristics of trailing-edge ailerons are superior to those of canard-delta ailerons. The latter are generally unsatisfactory because rolling moments produced are very small and their sign is changed for certain ranges of Mach number.

Compared to the planar wing with trailing-edge or canard-delta aileron, the equivalent cruciform wings have smaller rolling moment derivatives.

Results are plotted very instructively and are easy to use for engineering purposes. K. Flodin, Sweden

3156. Crocco, G. A., The crucial problem in astronautics. Recovery of multistage vehicles, *Jet Propulsion* **24,** 5, 313–315, Sept.-Oct. 1954.

From long experience in practical aeronautical development, author argues the advantages of a cautious step-by-step program of developing and proof-testing multistage orbital vehicles. In his view, each stage must be a complete flying machine capable of ascending into space and returning safely to earth. This paper, the first of two on the aerodynamic and mechanical problems of multistage rockets, deals with the problem of high-speed descent through the atmosphere and suggests means of avoiding destructively high temperatures. From author's summary

Aeroelasticity (Flutter, Divergence, etc.)

(See also Rev. 2952)

3157. Woods, L. C., Subsonic plane flow in an annulus or a channel with spacewise periodic boundary conditions. *Proc. roy. Soc. Lond.* (*A*) **229,** 1176, 63–85, Apr. 1955.

A solution is given for the velocity distribution in two-dimensional subsonic flows having periodic boundary conditions. The solution is exact for incompressible flow and approximate for the subsonic compressible case. Since boundary conditions must be transformed, the solution generally appears in the form of an integral equation which may be solved by iterative methods. The general formula is shown to reduce to previously derived forms when the period becomes infinite.

Application is made to the determination of the shape of the free surface of a liquid flowing over a periodic boundary (reference is made to the wrong figure), to oscillating airfoils (see following review), to incompressible flow in a closed circuit, and to the circulating flow about a constant-pressure bubble.

Paper represents a significant contribution to the basic mathematical theory of two-dimensional subsonic flow.

L. H. Schindel, USA

3158. Woods, L. C., The aerodynamic forces on an oscillating aerofoil in a free jet, *Proc. roy. Soc. Lond.* (*A*) **229,** 1177, 235–250, Apr. 1955.

The theorems previously derived by the author for plane subsonic flow with periodic boundary conditions (see preceding review) are applied to the calculation of the lift and pitching moment on an airfoil oscillating in a free jet. As the boundary of the jet is moved to infinity, the solution approaches Theordorsen's function for an airfoil oscillating in a free stream. The calculated difference between the forces in a free stream and in an open jet may be used to correct results obtained in open-jet wind tunnels. L. H. Schindel, USA

3159. Land, N. S., and Abbott, F. T., Jr., Method of controlling stiffness properties of a solid-construction model wing, *NACA TN* 3423, 21 pp., Apr. 1955.

Paper investigates the use of regular patterns of transverse holes to control the stiffness of otherwise solid plate wing models for use in wind-tunnel flutter tests. Results of an extensive test program give design data covering the range of flexural to torsional rigidity ratios between 0.6 and 2.8. On test, the holes must, of course, be filled with some soft "nonstructural" material.

W. S. Hemp, England

3160. Hedgepeth, J. M., Waner, P. G., Jr., and Kell, R. J., A simplified method for calculating aeroelastic effects on the roll of aircraft, *NACA TN* 3370, 26 pp., Mar. 1955.

An approximate linearized lifting-surface theory is used in conjunction with structural influence coefficients to formulate a method for analyzing the aeroelastic behavior in roll of an aircraft. Rolling effectiveness and aileron-reversal speed are computed by the use of a Galerkin-type procedure. Results obtained for two example configurations by using this method are compared with the results obtained by using the more refined method of *NACA TN* 3067 [AMR **7,** Rev. 3310]. The agreement is excellent. From authors' summary by L. Becker, USA

3161. Stein, M. L., Determining the mode shapes and frequencies of low aspect ratio multispar wings, *J. aero. Sci.* **22,** 2, 137–138, Feb. 1955.

Note in Readers' Forum.

3162. Küssner, H. G., Aeroelastic problems of airplane constructions (in German), *Z. Flugwiss.* **3,** 1, 1–18, 1955.

This review paper has the following sections: (1) Introduction, (2) Characteristics of aircraft vibration, (3) Theory of free vibrations, (4) Theory of air forces on vibrating lifting surfaces, (5) Two-dimensional solutions, (6) Three-dimensional solutions, (7) Improvement and experimental verification of the theory, (8) Matrix theory of wing flutter, (9) Numerical methods of solution, (10) Panel flutter, (11) Free vibration research, (12) Model research, (13) Flight research, (14) Prevention of flutter through rules of thumb ("Bauvorschriften").

The material of (4) and (5) is taken over from one of author's previous papers [AMR **7,** Rev. 3640] and has been criticized elsewhere by reviewer [AMR **8,** Rev. 738]. (10) is an extension of formulation of Hedgepeth, Budiansky and Leonard [AMR **8,** Rev. 757] to two-dimensional, plane panel, but no really new results are obtained. Paper, especially (11)–(14), should be of interest to practicing flutter analysts, but review can scarcely be considered comprehensive, and the sixty-five references to post-1945 literature do not appear to have been chosen in any systematic manner. J. W. Miles, USA

3163. Miles, J. W., On the nonlinear thickness effect for a supersonic oscillating airfoil, *J. aero. Sci.* **21,** 10, 714–715, Oct. 1954.

Note in Readers' Forum.

3164. Kusukawa, K., On the supersonic flow of elastic medium past a wedge, *Proc. 1st Japan nat. Congr. appl. Mech.*, 1951; Nat. Committee for Theor. appl. Mech., May 1952, 5–9.

Paper supplements author's previous papers [AMR **4,** Revs. 4089, 4090; AMR **5,** Rev. 375]. Linear (small strain) theory applied to title problem gives a solution containing a shock wave across which normal velocity component is discontinuous and an "equi-voluminal" discontinuity across which tangential component is discontinuous. L. Malvern, USA

3165. Cunningham, H. J., and Lundstrom, R. R., Description and analysis of a rocket-vehicle experiment on flutter involving wing deformation and body motions, *NACA TN* 3311, 26 pp., Jan. 1955.

Rocket vehicle tests (completed in 1950 but recently declassi-

fied) of an unswept wing indicated the significance of rigid body motions on flutter. Resultant flutter occurred at half the natural wing-bending frequency. Analyses in four degrees of freedom combining rigid pitch and translation with wing bending and torsion, confirmed tests; computed speed without aspect ratio or compressibility corrections were 30% lower than experimental. At present, such rigid body motion considerations are a part of standard flutter analyses. E. T. Welmers, USA

Propellers, Fans, Turbines, Pumps, etc.

(See Revs. 2972, 3020, 3072, 3142, 3156, 3166, 3187, 3188, 3191, 3192, 3204, 3221, 3233, 3235)

Flow and Flight Test Techniques

(See also Revs. 2983, 3097, 3110, 3122, 3135, 3136, 3137, 3138, 3152, 3154, 3158, 3193, 3203, 3216, 3259, 3262)

3166. Müller, H. P., Discharge measurements in penstocks (in German), *Wasserwirtschaft* 45, 8, 193–196, May 1955.

Investigations were performed in Voith hydraulic laboratory at Hermaringen, Germany, with series of current meters attached to a cross frame or shifted along a diameter in order to test performance of different size of runners, particularly the influence of the walls and the mutual interference. Several significant conclusions are presented concerning mutual distances. Measurement section must be located at least 15 times the penstock diameter downstream from any bends or other obstacles, and at least 5 times diameter from obstacles downstream. A small-sized current meter attached to the walls is suggested as an improvement for study of velocity distribution in that region. Article is a valuable contribution to classical methods of discharge measurement in penstocks, as part of turbine testing procedure.

S. Kolupaila, USA

3167. Buckingham, E., Notes on some recently published experiments on orifice meters, ASME Ann. Meet. N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-244, 49 pp.

Author presents a procedure for plotting orifice coefficient data which results in straight lines over a considerable range of conditions. By relating the slopes and intercepts of these lines to size ratio and the Reynolds number parameters, it is possible to represent the coefficients for a wide range of sizes and rates by two linear equations. By applying this procedure to several available sets of data he has determined the limits of applicability of the equations. Furthermore, he shows that the mechanical finish of the orifice plate surface and orifice edge affects both the slope and intercept of the lines resulting from the initial plottings.

From author's summary

3168. Howes, W. L., and Buchele, D. R., Generalization of gas-flow-interferometry theory and interferogram evaluation equations for one-dimensional density fields, *NACA TN* 3340, 70 pp., Feb. 1955.

Report constitutes extension of earlier work on refraction errors associated with gas-flow interferometry. Evaluation equations in generalized form are presented and then applied to the accurate calculation of one-dimensional density fields in which the refractive index is a monotonic function of a single Cartesian coordinate. Accuracy problems treated concern apparent-ray-trace crossing, plane of focus for the camera optics, light source geometry, convergence of the power series expansions for the density and optical distortion, and maximum values of density gradient consistent with the author's approximations. In reviewer's opinion, the important contributions in this paper include (1) the generalized formulation; (2) the comparison of point and extended sources; (3) a correctional procedure for refraction effects at any plane of focus (making it unnecessary to shift to the preferred plane at one-third span); (4) the reasonable agreement shown between theoretical results and measurements obtained from a well-designed experiment. It is comforting to note that the more intricate corrections assume importance only in regions of large density gradients, e.g., in a thin laminar boundary layer near the leading edge of a model. D. Bershader, USA

3169. Mason, H. L., Sensitivity and life data on Bourdon tubes, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-169, 16 pp.

Information supplied by manufacturers to the Empirical Data Subcommittee of the ASME Research Committee on Mechanical Pressure Elements is presented in tabular and graphic form. Sensitivities are compared with the theories of Wuest, Wolf, and Clark-Gilroy-Reissner. Plots of life data as a function of maximum fiber stress are shown for steel and for phosphor bronze.

From author's summary

3170. Grudemo, A., An automatically recording densitometer, *Appl. sci. Res.* (*B*) 4, 1/2, 3–9, 1954.

An instrument for the recording of photographic density distributions is described. It is based on the principle of continuous comparison of the density of points along a line on the moving film and the density of a gray wedge, the position of which is continuously set to balance by means of a servo system and recorded on a drum. Constructional details of the instrument are described, and the conditions of proper functioning are briefly discussed. From author's summary

3171. Beteille, R., Basic elements of measurements in flight (in French), *Publ. sci. tech. Min. Air. France. Bull. Serv. Tech.* no. 117, 247 pp., 1954.

The first part of this bulletin is a general theory of instruments under steady-state and transient conditions. Frequency-response and transfer functions are discussed. The second and third parts deal with measurements of pressure and temperature. There is no mention of specific makes of instruments, but such subjects as friction, leaks in tubing, and time lag are discussed in mathematical terms. The fourth part deals with flight measurements of altitude, Mach number, exterior temperature, and speed. An appendix gives a résumé of Laplace transformations and dimensional analysis. Finally, there is a good bibliography of articles and books on this subject from French, English, and German sources. This bulletin will probably be of interest mainly to French engineers working in the field.

W. C. Johnson, Jr., USA

3172. Sommer, S. C., and Short, Barbara J., Free-flight measurements of turbulent-boundary-layer skin friction in the presence of severe aerodynamic heating at Mach numbers from 2.8 to 7.0, *NACA TN* 3391, 47 pp., Mar. 1955.

Measurements of average skin friction of the turbulent boundary layer have been made in free flight at high rates of heat transfer at high Mach numbers. The results are appreciably higher than zero-heat-transfer wind-tunnel data. The T' method

for laminar boundary layers, slightly modified, is shown to agree with results of this and other investigations at widely different Mach numbers and heat-transfer conditions.

From authors' summary

3173. **Lukasiewicz, J., Development of large intermittent wind tunnels,** *J. roy. aero. Soc.* **59,** 532, 259–278, Apr. 1955.

Discusses design, performance, instrumentation, and operation of direct-discharge intermittent high-speed tunnels having pressure storage with atmospheric exhaust or vacuum storage with atmospheric inlet. Shows that pressure ratio vs. mass flow characteristics of tunnel and drive are well matched over wide Mach number range (0 to 4). Notes relative simplicity of design compared to continuous-running types. Gives experience at 30-in. × 16-in. intermittent tunnel, N.A.E. (Canada), and considers application to larger sizes (up to 6 ft square).

R. C. Pankhurst, England

3174. **Kraft, C. C., Jr., Flight measurements of the velocity distribution and persistence of the trailing vortices of an airplane,** *NACA TN* 3377, 32 pp., Mar. 1955.

Measurements have been made in flight of the velocity distribution and persistence of the trailing vortexes of a propeller-driven fighter-type airplane. The vortexes were marked in the atmosphere with smoke and were penetrated by a jet airplane equipped with a high-frequency angle-of-attack vane and a sensitive total-pressure instrument. Photographs of the trailing-vortex filaments were also made. From author's summary

3175. **Menard, M., and Monod, O., Supersonic nozzles with adjustable throats** (in French), *Publ. sci. tech. Min. Air, Paris* no. 51, 33 pp., 1955.

In a supersonic nozzle with a pair of flat sides, authors suggest use of a bulge or bump on each of these flat sides. Bulges are formed by cutting a body of revolution longitudinally, and their positions along axis of nozzle can be adjusted. When bulges are upstream of the throat formed in the basic nozzle, they have no effect on Mach number in supersonic part, but as bulges are moved downstream the effective throat area is changed and Mach number in working section varies.

Bulges are designed by one-dimensional theory, with allowance for boundary layer. Reviewer remarks that truly uniform supersonic flow in working section cannot be expected, using this method, but results of authors' experiments show that reasonably good flow, with Mach number constant within ±1.5%, can be obtained with a single nozzle for Mach numbers in working section between about 1.2 and 1.8.

A single bulge can also be used; this is particularly convenient in a wind tunnel designed for use with half-models, with only one wall of the nozzle curved. W. A. Mair, England

3176. **Heyson, H. H., Preliminary results from flow-field measurements around single and tandem rotors in the Langley full-scale tunnel,** *NACA TN* 3242, 19 pp., Nov. 1954.

Measurements of the flow angles and velocities near lifting helicopter rotors, both single and tandem, at a tip-speed ratio of 0.15 are presented and compared with those of theory. The comparison indicates that the theory is sufficiently accurate for use in preliminary design calculations. The flow behind a rotor is shown to be very much like the flow behind a wing.

From author's summary

3177. **Spiegel, J. M., and Tunnell, P. J., An analysis of shock-wave cancellation and reflection for porous walls which obey an exponential mass-flow pressure-difference relation,** *NACA TN* 3223, 23 pp., Aug. 1954.

A theoretical paper. Conditions for wave cancellation in two-dimensional wind tunnels using porous walls are developed. Paper extends earlier work by assuming exponential variation of flow with pressure difference across porous wall, an experimentally justified improvement on linear variation. Conditions for complete cancellation of reflected wave as well as strength for cases of partial cancellation are computed. W. Griffith, USA

3178. **Mattioli, E., Wind-tunnel measurements in non-steady flow** (in Italian), *Aerotecnica* **34,** 2, 83–85, Apr. 1954.

A brief account on the construction of a hot-wire anemometer and a strain-gage balance. From author's summary

3179. **Pascale, L., The smoke tunnel of the Institute of Aeronautical Engineering at the University of Naples** (in Italian), *Aerotecnica* **34,** 1, 16–22, Feb. 1954.

Paper presents the flow-visualization apparatus at the University of Naples. It is a smoke tunnel, with a working section of 87 × 57 × 10 cm.

The test chamber has glass side walls. Underneath the chamber the model support, the mechanism for changing the angle of attack, and other details are contained. Low turbulence is achieved with a high contraction of the entrance cone and with multiple screens. The tunnel has no return and is powered by a 1-hp electric motor.

The speed range used so far is between 4–15 m/s. The smoke is produced by burning wood under slight pressure, but with insufficient oxygen.

An electronic flash lamp is employed for photographic records. Some pictures are reproduced to show the possibilities of the apparatus. From author's summary

Thermodynamics

(See also Revs. 3020, 3055, 3072, 3089, 3104, 3115, 3122, 3123, 3124, 3167, 3171, 3175, 3194, 3196, 3207, 3211)

3180. **Mache, H., The impossibility of attaining absolute zero temperature and the normal form of any equation of state** (in German), *Öst. Ing.-Arch.* **8,** 2/3, 161–164, 1954.

Author's investigations of fundamental concepts in thermodynamics are introduced in two brief parts:

First part challenges the attainability of absolute zero temperature, the proof of which is not being offered, since the validity of the second law fails in the proximity of absolute zero temperature.

Second part of the paper refers to Clausius thermic equation of state as proposed standard form to derive the thermic and cohesion pressures.

Equations of Clausius and Berthelots are used in the arguments. Reviewer agrees with the author's summary statement, suggesting further gas-kinetical investigations.

C. R. Bell, USA

3181. **Bancroft, D., Calorimetric determination of absolute temperature,** *Amer. J. Phys.* **23,** 3, 142–147, Mar. 1955.

An undergraduate experiment is described for determining thermodynamic temperature directly from the definition of en-

tropy. A simple system is arranged so that the entropy change due to the addition of heat may be calculated from the resulting change in the pressure exerted by the system. For this calculation, the isentropic thermal expansion of the system must be determined experimentally. It is shown that, in principle, the temperature as determined does not require calibration of the thermometer used except at two fixed points. Accuracy of the order of 1% can be attained. From author's summary

3182. Kalafati, D. D., The region of water and melting ice on the S-T diagram (in Russian), *Zh. tekh. Fiz.* **24**, 2, 184–192, Feb. 1954.

Author claims that the general error in constructing an *S-T* diagram for water arises from the fact that it is considered a single phase system by various investigators, whereas it is actually a two-phase system.

The entropy of water at 0 C increases with pressure and has a maximum positive value at 180 atm. With pressures exceeding 180 atm, the entropy decreases and becomes zero at about 300 atm. With pressures above 300 atm, entropy assumes negative values. This is in disagreement with values given in thermodynamic tables for properties of water at 0 C. The existing tables show entropy increase at 300 atm.

It is erroneous, according to author, to present water isobar on *S-T* diagram as an equidistant logarithmic curve, or crossing at 4 C on the boundary curve, or beginning at a point of 4 C on the *T* axis. W. Green, USA

3183. Bleyle, G. A., Hinckley, R. B., and Jewett, C. L., An air-transportable liquid oxygen generator—its operation and application, *Jet Propulsion* **24**, 5, 297–301, Sept.-Oct. 1954.

3184. Patterson, G. N., Mechanics of rarefied gases, *Proc. 2nd Canadian Symposium on Aerodynamics, Inst. of Aerophysics, Univ. of Toronto*, Feb. 1954, 151–166.

A brief survey of some of the problems of rarefied gas flow is presented. The free-molecule and slip flow regimes are discussed, and some of the important parameters are exhibited. L. Talbot, USA

3185. Kosin, R. E., On a not widely known relation between Reynolds number and magnitudes of the kinetic theory of gases, *Z. Flugwiss.* **2**, 11, 298–299, Nov. 1954.

3186. Rosenberg, H. M., The thermal conductivity of metals of low temperatures, *Phil. Trans. roy. Soc. Lond.* (*A*) **247**, 933, 441–497, Mar. 1955.

The thermal conductivity of high-purity samples of thirty-one metals has been measured. These were Ag, Al, Au, Be, Cb, Cd, Ce, Co, Cu, Fe, Ga, In, Ir, La, Mg, Mn, Mo, Ni, Pb, Pt, Rh, Sb, Sn, Ta, Ti, Tl, U, V, W, Zn, and Zr. For most metals measurements were taken from 2 to 40 K, but where necessary they were extended to 90 K. For superconductors they were taken in both the superconducting and normal states. The conductivity was found to be entirely electronic except for Sb and U. Most of the specimens were polycrystalline, but single crystals of Zn, Cd, Sn, Pb, Ga, and Ti were measured. For Zn and Ga, specimens of different orientations with respect to the rod axis were obtained, and in both these metals the thermal conductivity was found to be anisotropic.

The thermal resistance W at low temperatures of nearly all the metals is of the form $W = \alpha T^2 + \beta/T$, and the constants α and β have been calculated. If K_∞ is the limiting thermal conductivity at high temperatures and θ is the Debye temperature, then the value of $\alpha K_\infty \theta^2$ is the same for the metals in any one chemical group. For some metals, the electrical resistance was measured at the same time as the thermal conductivity over the full temperature range and hence the Lorenz number L was calculated. The limiting value of L at low temperatures for several metals was found to be considerably higher than the theoretical value, in particular for Ti and Zr. A corresponding effect to the minimum in the electrical resistance of Mg has been found in the thermal resistance. A large increase in the thermal conductivity of Fe after a period of time has been ascribed to the precipitation of impurities in the metal. A method is given for estimating the thermal conductivity of a metal at low temperatures. From author's summary

3187. Ross, A. O., and Huppert, M. C., Analytical determination of effect of water injection on power output of turbine-propeller engine, *NACA TN* 3403, 29 pp., Mar. 1955.

Investigation is made for engines with a centrifugal compressor, having compressor tip speeds of 1200, 1500, and 1800 fps. The wet compression process is assumed as polytropic, and empirical constants are determined from the available experimental data.

The results indicate that, with the use of water injection, the shaft power of the engine may be increased by more than 78% at a compressor speed of 1800 fps without increase in turbine-inlet temperature. It requires the liquid consumption to be increased 4.5 times.

It is shown also that by injecting sufficient amount of water to saturate the air at the compressor outlet, 200% in power increase is possible at a compressor tip speed of 1800 fps. From authors' summary by K. Pilarczyk, USA

3188. Bean, H. S., Johnson, R. M., and Blakeslee, T. R., Small nozzles and low values of diameter ratio, *Trans. ASME* **76**, 6, 863–871, Aug. 1954.

See AMR 7, Rev. 1923.

3189. Ketnath, A., Heat measurements in steam power plants [Das wärmetechnische Messwesen in Dampfkraftwerken und Industriebetrieben], Berlin, Springer-Verlag, 1954, ix + 222 pp., 140 figs. DM 25.50.

Book is written for design engineers and contains the description of instruments and control instruments used in steam power plants. It is clearly written and explains the subject, without any higher mathematics, in a pleasant and entertaining manner.

It is composed of three parts: In part I, installations are described; in part II, point of view of design is discussed; in part III, there are a few illustrated examples.

Though the book is thorough, described instruments are only of German manufacture, although there is no doubt that in "extra Germaniam," you will also find good instruments. The first part of the book is clear, but the second part is condensed to such an extent that even the expert cannot follow it without difficulty in certain parts.

The reviewer disagrees, however, with several aspects of the third part in which instruments are described with several functions. He believes that the simplest instrument requiring the least surveillance serves its purpose best. He does not think that a complex instrument for a boiler efficiency meter can ever be

useful. Reviewer hopes that his suggestions will be of some value in the next edition. S. Apáti, Hungary

3190. Mayer, H., The cold end in steam circle processes (in German), *Brennstoff-Wärme-Kraft* **7**, 2, 68–73, Feb. 1955.

3191. Ellrich, W., Development problems in steam power plants (in German), *Brennstoff-Wärme-Kraft* **7**, 2, 47–54, Feb. 1955.

3192. Giroux, C. H., Stephens, J. O., and Nolte, R. J., A 5000-KW railway-mounted gas-turbine power plant, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-191, 15 pp.

The Corps of Engineers, recognizing a need for mobile power plants of a larger output than can be obtained with conventional drives, turned to the gas turbine as a solution to this problem. This paper describes the construction of a 5000-kw power plant, mounted on two railway cars, suitable for service throughout most parts of the world. From authors' summary

3193. Kratz, E. M., Experience in testing large steam turbine-generators in central stations, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-258, 12 pp.

The purpose of this paper is to make the testing techniques established as a result of author's company (General Electric) experience available to the power industry and especially to those directly concerned with tests on central station equipment.

From author's summary

Heat and Mass Transfer

(See also Revs. 2960, 2964, 3002, 3004, 3005, 3021, 3055, 3089, 3132, 3171, 3181, 3186, 3189, 3191, 3220, 3225, 3227)

3194. Stoll, Alice M., and Hardy, J. S., Thermal radiation measurements in summer and winter Alaskan climates, *Trans. Amer. geophys. Un.* **36**, 2, 213–226, Apr. 1955.

Thermal characteristics of the summer and winter Alaskan climates were evaluated by two methods: (1) direct measurement of solar and low-temperature radiation exchange by means of the panradiometer (an absolute radiation-measuring device described briefly) and, by computation from the measured values, the mean radiant temperature of the environment; and (2) the direct measurement of the mean radiant temperature of the environment with the thermo-radiometer (which instrument and method of use are also described briefly) and, by computation from these measurements, the solar contribution to the total radiation. During the summer period, the solar radiant flux occasionally exceeded 800 kg cal/m² hr. The mean radiant temperature of the environment varied from 8 C to 51 C, undergoing large and sometimes rapid changes as the intensity of solar radiation varied with sky cover. During the winter period, the solar radiation attained only 10 to 30% of the summer intensity. The mean radiant temperature varied from −3 C to −55 C and depended strongly on the radiant temperature of the sky, a concept introduced for simplification of the radiation-exchange problem. The latter temperature was greatly influenced by the water vapor content of the atmosphere. From authors' summary

3195. Thring, M. W., and Smith, D., An improved model for the calculation of heat transfer in the O. H. furnace, *J. Iron Steel Inst.* **179**, part 3, 227–230, Mar. 1955.

Author designed a new model for use in calculating average roof temperature and thermal efficiency during the melting period and the melting time at various fuel input rates. Previous models were improved with respect to the flame-covered area, assuming that the flame covers only the half width of the bath at the outgoing end. Taking, furthermore, the resistance to heat transfer through the slag as being equivalent to about that of one inch of solid steel, author succeeded in working out the values which are in close agreement with the observed melting time, thermal efficiency, and the maximum fuel input rate for a given maximum roof temperature.

Reviewer believes that this series of work shows brilliant achievements which give important background to the design and operation of O. H. furnaces. I. Sawai, Japan

3196. Hemenway, H. H., Radiant superheater—design and experience, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-255, 29 pp.

The development of radiant superheaters and reheaters over the past thirty-five years is outlined. Operational experience is described. From author's summary

3197. Pengelly, A. E., Heat transfer through oxide-cathode materials, *Brit. J. appl. Phys.* **6**, 1, 18–20, Jan. 1955.

The thermal conductivity of polycrystalline barium oxide, strontium oxide, and an equimolecular mixture of the two, with and without the addition of $2^1/_2$% zirconium oxide or 5% zirconium, was carefully measured in vacuum for a mean temperature range of 150 C to 750 C. A 0.9-mm layer of material was located between nickel disks containing heaters. Heat transfer was effected by heating one disk, and the amount of heat transferred was determined by the temperature of the unheated disk from previous calibration.

It was found that the thermal conductivity was strongly influenced by the mean temperature, and this effect was attributed to radiation. The absorption and scattering coefficients were calculated from the heat-transfer equation, which included radiation terms.

Reviewer believes that the experimental work is valuable, but the contribution of radiation is overstated in the paper. Consideration should be given to the larger number of conduction electrons which become available with increased temperature in the materials studied. R. H. Eustis, USA

3198. Richards, P. B., The temperature distribution in a nuclear reactor pierced by circular cooling channels, *Nuclear Engng. Part I, A.I.Ch.E. Chem. Engng. Progr.* **50**, *Symp. Series* no. 11, 127–133, 1954.

Author is concerned with the problem of estimating temperatures in the core of a nuclear reactor. The core model is a solid block of reacting material pierced by holes through which coolant flows. In the interior of the block, a uniform neutron concentration may be assumed, resulting in a uniform rate of heat release in the reacting core. In this region, the heat flow may be taken as two-dimensional from the reacting material, through the nonreacting coolant channel walls, into the coolant.

Author applies the method of relaxation described by Emmons [*Quart. appl. Math.* **2**, 3, 173–195, Oct. 1944], and Dusinberre [AMR **3**, Rev. 1370] to the difference calculation of heat conduction with varied boundary conditions. This method is not rigorous, nor does it, because of the two-dimensional limitations and the assumption of uniform neutron concentration, take account of boundary effects at the outside of the core. It is, however, probably adequate for the objective of this paper, which is to

provide an estimate of the maximum temperature within the selected core model. M. A. Mayers, USA

3199. Kazakevich, F. P., Effect of the angle of incidence of a gaseous flow on the heat emission of a round cylinder (in Russian), *Zh. tekh. Fiz.* 24, 7, 1341–1349, July 1954.

Author describes an investigation to determine the mean value of heat emission coefficients from a cylindrical surface, when a stream of heated air is swept at an angle of 30, 45, 60, 75, 82, and 90 degrees over the surface. Reynolds number in this stream was from 3500 to 50,000.

Results of the investigation show, according to author, that there is a definite relationship between heat emission from a cylindrical surface and the angle of incidence.

A series of graphs show heat emission distribution over a cylindrical surface when the angle of incidence is 30°, 60°, and 90° with $Re \simeq 11{,}000$ and $\simeq 20{,}700$. W. Green, USA

3200. Lauwerier, H. A., The transport of heat in an oil layer caused by the injection of hot fluid, *Appl. sci. Res.* (*A*) 5, 2/3, 145–150, 1955.

The possibility of supplying heat to a petroleum reservoir by injecting hot water is investigated using an idealized mathematical model. Author assumes that the water flows at a uniform velocity in a separate layer of constant thickness bounded above and below by oil sands, zero thermal conductivity in the direction of flow, infinite conductivity in the water layer perpendicular to the direction of flow, and instantaneous thermal equilibrium between the sand grains and the surrounding fluid. The resulting partial differential equation is solved using Laplace transforms, yielding equations for the temperatures in the oil layer and in the water layer as a function of location and time.

Reviewer believes that the Dietz "theory" on which the mathematical model is based is only a first approximation and that the results of this analysis should not be applied directly in field work. Also, the mechanism of heat transport in porous materials is still open to question [see, e.g., Jenkins and Aronofsky, *Producers Monthly* 19, 5, 37–41, Mar. 1955]. G. C. Wallick, USA

3201. Korobkin, I., On the determination of local heat-transfer coefficients for bodies with pressure gradient in supersonic flow, *J. aero. Sci.* 22, 4, 283–284, Apr. 1955.

Note in Readers' Forum.

3202. Clarke, L., and Winston, R. E., Calculation of finside coefficients in longitudinal finned-tube exchangers, *Chem. Engng. Progr.* 51, 3, 147–150, Mar. 1955.

3203. Brevoort, M. J., and Rashis, B., Turbulent-heat-transfer measurements at a Mach number of 2.06, *NACA TN* 3374, 20 pp., Mar. 1955.

An axially symmetric annular nozzle was used to obtain essentially flat-plate data on turbulent heat-transfer coefficients and temperature-recovery factors. The test results of this paper are for Mach number 2.06 and for a Reynolds number range of 1.7×10^6 to 8.8×10^7. The heat-transfer-coefficient results are in good agreement with theoretical analyses and the experimental results of the tests of V-2 rockets. The recovery factors are approximately 0.5% lower than data for a Mach number of 2.4.

From authors' summary

3204. Sparrow, E. M., Analysis of laminar forced-convection heat transfer in entrance region of flat rectangular ducts, *NACA TN* 3331, 42 pp., Jan. 1955.

Using von Kármán-Pohlhausen method, author studies the development of both velocity and thermal boundary layers of a steady laminar flow of an incompressible fluid in the entrance region of flat rectangular ducts. Two thermal boundary conditions at duct walls are investigated: (1) both walls at same uniform temperature, and (2) one wall at uniform temperature and other wall insulated. All fluid properties are assumed to be constant.

Results are reported in terms of Nusselt numbers versus Graetz numbers at specific values of Prandtl number ranging from 0.01 to 50. They are also compared with results obtained for a developing thermal boundary layer with a fully developed velocity profile and with those obtained for flow over a flat plate.

T. Y. Toong, USA

3205. Brun, R. J., and Dorsch, R. G., Variation of local liquid-water concentration about an ellipsoid of fineness ratio 10 moving in a droplet field, *NACA TN* 3410, 51 pp., Apr. 1955.

This note is another in a series of NACA reports on the trajectories of water droplets around aerodynamic shapes. This report and one of its references will be useful to aircraft designers who must locate various protuberances on aircraft and desire to avoid regions of high icing intensity.

M. Tribus, USA

3206. Brun, E. A., Review of icing research (in French), *Proc. 3rd AGARD Gen. Assembly*, AGARD AG6/P3, 27–40, Sept. 1953.

3207. Andreeva, M. K., Investigation of heat and mass transfer during the progress of wetting (in Russian), *Zh. tekh. Fiz.* 24, 11, 1966–1973, Nov. 1954.

In author's experiments, a plate of asbestos ($9 \times 9 \times 0.95$ cm^3) is suspended on the arm of a balance and exposed to air of uniform temperature and humidity. Adsorption of water begins immediately; its rate is determined by weighing over a time interval up to 120 min. Using a micro-hair-hygrometer and a thermocouple as probes, the distribution of temperature and humidity is investigated. At points situated 0.8–10 mm off the surface of the plate, the temperature rises at first and decreases subsequently; humidity increases steadily; after approximately 1 hr, both quantities approach to the values prevailing at large distances from the surface. Graphs showing the results of measurements are, unfortunately, incomplete, covering only a small fraction of the experiments made and excluding the initial stages of single experiments. It is found that the gradients of humidity and temperature tend to a well-defined finite limit near the surface. Author's deductions from his work are presented by plotting log Nu against the log of powers of $Gr \times Pr \times$ relative humidity, where the symbols stand for Nusselt, Grashof, and Prandtl numbers. Author shows that experimental points admit interpolation by a straight line. Author rejects any interpretation of his results in terms of diffusion and thermal conduction. He does not indicate whether the simple relation between the transfer of heat and mass, as suggested by the kinetic theory of the surface layer, holds good.

Reviewer regrets that the use of author's important results is impaired by inadequate presentation.

R. Eisenschitz, England

3208. **Hickman, K. C. D., Maximum evaporation coefficient of water,** *Indust. Engng. Chem.* **46,** 7, 1442–1446, July 1954.

Evaporation rate of carefully prepared degassed water was measured in simple glass apparatus providing high-velocity free jet with surface having average age of less than 0.001 sec. Runs were conducted under vacuum with 5 to 7 C water temperature. Icing terminated most runs after 5 sec, but a few lasted 5 min or more.

Evaporation coefficients were calculated and found to range from not less than 0.254 to 0.446 or higher. These values are 25 to 100 times greater than previously reported for water. They indicate that abnormalities usually attributed to water are probably due to surface impurities usually present.

J. N. Addoms, USA

3209. **Hickman, K. C. D., and Torpey, W. A., Evaporation of resting water,** *Indust. Engng. Chem.* **46,** 7, 1446–1450, July 1954.

Authors report visual observations of surface of water boiling under vacuum in pot still. Surface emissivity for vapor as indicated by surface craters is discussed with respect to pretreatment of water and time since last purification. Numerous photographs of so-called schizoid surfaces and of ice formation are shown.

Authors found approximate evaporation coefficient of resting water varied from 0.001 to 0.02. They postulated chemical impurity as SiO_2 in surface layer as the most likely cause for blocked surface. Experiments to confirm hypothesis were performed in varnish-coated flask; they showed that added silicate did not decrease emissivity, but HF, which was added to remove surface SiO_2 impurity, gave most highly blocked surface of all! Authors recommend further work with conductivity water.

J. N. Addoms, USA

3210. **Stein, R. P., Hoopes, J. W., Jr., Markels, M., Jr., Selke, W. A., Bendler, A. J., and Bonilla, C. F., Pressure drop and heat transfer to nonboiling and boiling water in turbulent flow in an internally heated annulus,** *Nuclear Engng. Part I, A.I.Ch.E. Chem. Engng. Progr. Symp. Series* no. 11, **50,** 115–126, 1954.

A valuable addition to the previous works concerning pressure drop and heat-transfer data for water being heated in annuli. This paper considers very long annuli, eccentric annuli, high fluid velocities, high heat-transfer rates, cosine distribution of heat transfer, centering ribs, and the existence of boiling.

Deionized water was pumped through annuli $^1/_8$ in. wide, 1.08-in. ID and 14 ft long for both boiling and nonboiling. The flow was measured by an orifice meter. The heated section consisted of an inner tube of 2S aluminum, 1.08-in. OD, 14 ft heated length, and an outer 61S aluminum housing tube, with a $^1/_8$-annulus between them. There was no initial unheated calming length. The inner tube was heated by direct current passing through it. The annuli had maximum design eccentricities of 0.038 and 0.003 in., or 30 and 3% of annulus width.

The nonboiling friction factors agree quite well with pipe values in the case of concentric annuli, and in the eccentric case were approximately 30% low. Average local heat-transfer coefficients agree quite well with the Colburn j factor for turbulent flow inside tubes and are substantially independent of eccentricity.

Inlet pressures during coolant boiling were checked by two incremental calculation methods. Homogeneous or "fog" flow gave inlet pressures which were somewhat high, and Martinelli and Nelson's "slip" flow gave pressures too low.

A modified plot by Lockhart and Martinelli was obtained which gives good agreement in calculating two-phase frictional pressure drop for the runs reported. C. C. Eckles, USA

3211. **Zabronsky, H., Temperature distribution and efficiency of a heat exchanger using square fins on round tubes,** *J. appl. Mech.* **22,** 1, 119–122, Mar. 1955.

Analytical solution is presented for subject fin with expressions for temperature distribution and fin efficiency in terms of Bessel functions. Comparison of square fin with round fin of equal area shows square fin to have only slightly lower fin efficiency, varying from approximately 0.5% lower for tube diameter 20% of square fin width to 2.0% lower for tube diameter 80% of fin width. Typical curve of variation in fin efficiency with relative tube diameter, and typical temperature distribution pattern for square fin are given. O. P. Bergelin, USA

3212. **Véron, M., and Trèves, F., Analytic study of heat exchangers with isothermal envelope** (in French), *Bull. tech. Soc. Franc. Const.* (Babcock & Wilcox) no. 27, 23–73, Oct. 1954.

A straightforward formal solution of the generalized bayonet-heater problem: two steady streams, counter or concurrent, that can exchange heat with each other are able individually to gain heat from or lose heat to the same constant-temperature environment. The ratio of the streams is unrestricted. Over-all heat-transfer coefficients, although not necessarily the same for the different heat-transfer surfaces, are supposed uniform for each surface. T. B. Drew, USA

3213. **Hafer, A. A., and Wilson, W. B., Gas-turbine exhaust-heat recovery,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-194, 29 pp.

Paper discusses a number of possible ways of utilizing the energy contained in the gas-turbine exhaust. Such methods as regeneration, feedwater heaters, exhaust-heat-recovery boilers, fuel-fired boilers, stack ejectors, and the exhaust-fired cycle are considered. The thermodynamic and economic aspects of these various methods of utilizing the exhaust are analyzed. Data are presented on the gas turbines manufactured by the authors' company to illustrate actual installations utilizing the gas-turbine exhaust energy. Curves are included which indicate the quantity of steam which may be generated utilizing the turbine-exhaust energy at various steam conditions.

From authors' summary

3214. **Spalding, D. B., The calculation of mass transfer rates in absorption, vaporization, condensation and combustion processes,** *Proc. Instn. mech. Engrs.* **168,** 19, 545–570, 1954.

Author shows the essential unity of mass-transfer phenomena in a variety of processes by use of appropriate transfer numbers related to mass and thermal properties. It is shown to be possible to compute with fair precision the mass transfer by making use of heat- or momentum-transfer data. This idea is, of course, not new, but, by the use of slightly modified concepts, the wider range of use indicated is made easier.

Although the many cases indicated are discussed, only very few cases are checked against experimental results. The most important check is that with combustion of liquid fuels, which has already been published elsewhere by the author. This lack of experimental check in the various fields of application makes it difficult for the reader to determine with just what accuracy results are being obtained. The derivations have included a great many minor ad hoc assumptions which, in many cases, are essential because of the complexity of the problems concerned. However, the accumulated effect of such assumptions in any given case makes it difficult to judge the resulting precision.

This paper would be of most value to engineers, since it permits a more rapid estimate to be made with probable greater precision than earlier methods have permitted. H. W. Emmons, USA

3215. Gaylord, E. W., and Forstall, W., Measurement of mass transfer by an electrical conductivity method, *Brit. J. appl. Phys.* 6, 4, 135–138, Apr. 1955.

A method has been developed to study the diffusion of fresh water into salt water using electrical conductivity cells in such a manner that it is possible to determine continuously, rapidly, and inexpensively what portion of any sample of the mixture came from the salt water, and what portion came from the fresh water. The method is one of comparison; an exact determination of the salt concentration of the salt water before mixing is not required. The method is restricted to the study of incompressible-flow problems and subject to the limitations imposed by the use of water.

From authors' summary

3216. Foster, J. V., Two miniature temperature recorders for flight use, *NACA TN* 3392, 13 pp., Apr. 1955.

Descriptions are given for two types of temperature recorders suitable for use with thermocouples on fighter-type aircraft. One is an electromechanical self-balancing potentiometer type; the other uses electronic feedback to achieve fast balance.

From author's summary

3217. Ekelöf, S., and Kihlberg, G., Theory of the thermistor as an electric circuit element. A study of thermistor circuits, *Trans. Chalmers Univ. Technol.* 142, 35 pp., 1954.

The basic physical and thematical concepts underlying the calculation of electric circuits containing thermistors are presented. The advantage of replacing the thermistor temperature as a variable with the dissipated power is stressed.

The important power balance equation (the thermistor equation) is written in a form containing the thermal time constant. From this equation, equivalent circuits of "thermo-positive" and "thermo-negative" resistors are deduced which allow the calculation of superposed variable states.

Some simple applications are given.

From authors' summary

Combustion

(See also Revs. 2960, 3195, 3213, 3214)

3218. Badami, G. N., and Egerton, A., The determination of burning velocities of slow flames, *Proc. roy. Soc. Lond.* (*A*) 228, 1174, 297–322, Mar. 1955.

Measurements of the burning velocities of lean mixtures of methane, ethane, propane, butane, ethylene, carbon monoxide, and cyanogen with air, in the range about 4 to 8 cm/s, made by the flat-flame burner method with an accuracy of 2 to 3% are reported. The results can be represented by a straight-line relationship between composition and burning velocity except for carbon monoxide, which is sensitive to the percentage of water vapor present. Measurements are also reported on binary mixtures with air of the gases, including hydrogen. The mixture law holds except with mixtures containing carbon monoxide.

Limits of inflammability are also determined, and the burning velocities at the limits average 3.6 cm/s.

The burning velocities of the hydrocarbons can be represented approximately by a straight-line relationship with the heat generated and with the maximum flame temperature, but correlation is best when thermal conductivity is introduced. At a given velocity, the excess energy maintained by the flame appears to be constant for all the hydrocarbons investigated, except methane which behaves slightly differently.

From authors' summary by T. L. Cottrell, Scotland

3219. Véron, M., and Dumortier, J., Some experimental studies of combustion (in French), *Bull. Tech. Soc. Franc. Const.*, (Babcock & Wilcox) no. 27, 7–13, Oct. 1954.

Paper deals with the determination of inflammation temperatures of traces of CO in the presence of O_2, in contact with steel walls of varying temperatures. The reinflammation of traces of CO in fumes produces a local rise of temperature, increasing the temperature gradient and the heat transfer by convection.

From authors' summary by H. Behrens, Germany

3220. Hattori, H., Koizumi, M., and Sasaki, T., Study on the ignition of pulverized coal combustion (in Japanese), *Trans. Japan Soc. mech. Engrs.* 20, 100, 821–826, 1954.

Authors discovered a new experimental method to measure the flame propagation velocities of the mixture of pulverized coal and air. In this method, the coal-air mixture is fed into the open atmosphere as free-bounded flow, in whose center a small C_2H_2 gas flame is placed as an ignition flame, so that the steady flame front of inverted cone shape may be formed in the mixture due to the balance of flame propagation velocity and flow velocity.

Authors propose also a theoretical formula to include flame velocity from flow velocity, cone angle, and density drop at flame front.

Using authors' method, the following themes are studied: (1) The relation of ignition burner flow rates to flame velocity; (2) the relation of mixture flow velocities to flame velocity; (3) the relation of pulverized coal concentration to flame velocity; and (4) the relation of grain sizes of pulverized coal to flame velocity.

As a result of study of (1) and (2), it has been found that the ignition flame size and mixture flow velocity have little effect on flame velocity, and the proposed formula is proved right.

On the other hand, coal concentration and grain sizes have definite effects as follows: The mixture has maximum velocity at its proper concentration as does a gas mixture, and flame velocity increases as grain size decreases. From authors' summary

3221. Cheng, S.-I., Unconditional stability of low-frequency oscillation in liquid rockets, *Jet Propulsion* 24, 5, 310–312, 315, Sept.-Oct. 1954.

In order to exhibit instability, rocket motor requires a certain amount of excitation energy, provided by combustion process. Stabler motors require more excitation. Author applied idea to low-frequency instability. As measure of excitation energy, author chooses the value of so-called interaction index between pressure oscillations and combustion processes. For given feed system, the interaction index required to produce neutral oscillations is a function of the frequency, which can be obtained either from design data or from hydraulic tests made on the feed system without rocket firing, and exhibits a minimum at some frequency. If interaction index of given propellant is smaller than minimum required, the motor is unconditionally stable. In opposite case, one can modify through servo controls the feed system characteristics so that minimum required interaction index becomes

larger than actual value for given propellant. Author produces explicit determination of required transfer function of servo control for both monopropellant and bipropellant cases.

L. Crocco, USA

3222. Moen, W. B., and Shepherd, T. L., Flame-stabilized oxy-fuel gas burners, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-193, 9 pp.

An oxy-fuel gas burner characterized by extremely high rates of heat release and energy transfer to a workpiece recently has been developed. The design considerations necessary for optimum performance include a determination of favorable geometric configuration, and fuel selection and operating conditions. Any applications where rapid rates of heating are required, not within the confines of a furnace, are suggested.

From authors' summary

3223. Speisher, V. A., Limits of gas combustion stability in a tunnel-type jet (in Russian), *Izv. Akad. Nauk Otd. tekh. Nauk* no. 6, 145–150, June 1954.

Effect of tunnel diameter on stability region of tunnel burner flames was investigated. Jet size remained constant at 18 mm, and three refractory tunnels of diameters 27, 48, and 70 mm were employed. Flow velocity W at nozzle was plotted against air/gas ratio (α) for incipient "blow off" as upper limit, and flame lift (due to primary air deficiency) as lower limit of stability. With large tunnel, flow velocity of 260 m/sec and heat output 1.4×10^6 cals/m^2_3/sec were attained.

Region of greatest stability for any tunnel occurred with approximately stoichiometric air/gas ratio, as did maximum in temperature and burning velocity curves. Effect of gas composition was also investigated using the 27-mm tunnel. Increase in H_2 and decrease in CH_4 widened stability region. Plot of flow velocity at stability limit, against corresponding combustion velocity, gave series of straight lines for different diameter tunnels.

Relationship $W \sim K\nu u/a$ was derived, where a is thermal conductivity of mixture, ν kinematic viscosity, and u normal combustion velocity. This does not explain influence of tunnel diameter and is to be compared with $W \sim u^2$, obtained by other workers using baffles to stabilize the flame.

J. K. Kilham, England

3224. Monnot, G., Contribution to the temperature measurement of luminous flames (in French), *Rev. Inst. fr. Petr. et Ann. Combust. liq.* **9**, 11, 12; 587–613, 740–763, Nov., Dec. 1954.

Construction of two optical pyrometers is described, one based on monochromatic light and the other employing the two-color principle. In each case, rapidly responding photocells are used as sensing elements. These instruments may be used to measure temperatures of yellow flames containing carbon particles. Results of measurements of an oil diffusion flame in a furnace and combustion in a diesel cylinder are presented.

R. Friedman, USA

3225. Friedman, R., and Burke, E., Measurement of temperature distribution in a low-pressure flat flame, *J. chem. Phys.* **22**, 5, 824–830, May 1954.

From careful thermocouple measurements with a very fine ceramic-coated platinum-platinum 10 Rhodium cylinder of 0.0066-cm diam, authors obtain temperature distribution in reaction zone of lean, flat, propane-air flame at 0.0594 atm. Effective temperature rise occurs in region 300 times greater than cylinder diameter. Data are reproducible with good resolution. Analysis is made to obtain pattern of heat release based on heat conduction equation with assumptions as to variation of heat conductivity and specific heat with temperature. Reasonable heat-release pattern is obtained indicating concentrated reaction zone of order $^1/_4$ the zone of temperature rise. Conclusions as to position of concentrated heat release and effective "ignition" temperature are indicated to hinge greatly on power of λ/C_p. Use of 0.75–0.93 as temperature variation power leads to 300 to 1000 C as ignition point. Activation energy estimates based on maximum heat-release rate give 23–30 kcal for reaction. Flame speed measurements made show variation with inverse 0.30 power of pressure.

M. Gilbert, USA

3226. Schalla, Rose L., Clark, T. P., and McDonald, G. E., Formation and combustion of smoke in laminar flames, *NACA Rep.* 1186, 21 pp., 1954.

We think the authors have neglected what we have reason to believe is a very important factor in the rate of smoke production for burning of hydrocarbons. This factor is the effect of water-vapor on the combustion reactions. We find no reference to the presence or absence of water vapor.

We find too, that the C/H ratio by weight of the fuel is very significant for smoke production. We find that the relative refractoriness of the molecule is equally significant. Ready disassociation produces free carbon in a zone which is masked from O_2. This carbon moves out of a temperature zone which would permit oxidation before O_2 is at hand.

Water vapor, through disassociation, in a typical water-gas reaction delivers both H_2 and O_2 in diffusion throughout the combustion zone. The masking suggested in the preceding paragraph is not present. We also have reason to believe that water-vapor facilitates the production of a state of slight hydroxylation at the envelope of the flame to consume a part of the fuel through partial oxidation on a step-by-step basis.

The importance of water vapor in the combustion reaction is clearly shown in that a mixture of anhydrous air and fuel shows a much higher kindling temperature than is the case where some water vapor is present at the point of kindling.

We have found that a continued state of turbulence following initiation of combustion tends to reduce the amount of smoke formed for any reference fuel. The turbulence counters the "masking effect" as discussed. We feel there is material for a new paper in continuance of this excellent study in which the effect of turbulence and the effect of water vapor have adequate treatment.

R. D. Reed, USA

3227. Leah, A. S., Godrich, J., and Jack, H. R. S., Radiation and chemiluminescence from explosion flames of carbon monoxide, *Fuel* **34**, 2, 133–152, Apr. 1955.

It is shown that, with explosions of mixtures of carbon monoxide and air and of carbon monoxide and oxygen, the radiation emitted during the early stages of reaction is largely of chemiluminescent origin; quantitative values have been obtained for the thermal and chemiluminescent contributions. In line with W. E. Garner's findings, the effect of water vapor and hydrogen in quenching the chemiluminescence has been demonstrated and notable "delay period" has been observed during which no measurable radiation is emitted. The reaction zone has also been shown to be of considerable depth behind the visible flame front.

From authors' summary

3228. Cohen, L., and Luft, N. W., Combustion of dust layers in still air, *Fuel* **34,** 2, 154–163, Apr. 1955.

The rate of burning of dust layers is of importance in industrial fire hazards and represents a special case in fuel bed reactions. A simple experimental technique is described and results are presented of its application to 18 different dusts of industrial interest. Three types of propagation are distinguished, dependent on dust and/or method of ignition: (a) smoldering, (b) diffusion flame above molten layer, and (c) diffusion flame supported by decomposition of layers. Apart from magnesium powder, temperatures indicated by thermocouple in dust layers are surprisingly low. In general, the burning velocity increases with increasing layer depth and decreasing particle size; thus, a propagation limit may be defined by minimum depth of layer and maximum particle size. A simplified hypothesis of the propagation mechanism is presented.

The reviewer feels that, as particle size range is often ill-defined and size distributions are not given, the work could be extended profitably by the study of dusts of narrow size range, prepared by elutriation.

D. B. Leason, England

3229. Mann, C. P., Heat-processing combustible materials by high-temperature gas-generated radiation and by direct flame impingement, ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-163, 10 pp.

The rate of production, economy, and/or the quality of many combustible materials, such as paper, textiles, and plastics, is frequently limited by the heat-processing operations applied in their manufacture. High-temperature radiant heat and direct-flame contact on these materials have overcome the limitation imposed by slow heating methods, and this paper describes these new techniques and illustrates a number of typical applications.

From author's summary

3230. Eigen, H., Contribution to the model computation of cylindrical rotary kilns (in German), *Zement-Kalk-Gips* **7,** 11, 434–436, Nov. 1954.

Acoustics

(See also Revs. 2960, 2991, 3084)

3231. Carrier, G. F., On acoustic resistance to the transient motions of an immersed shell, *Rev. Fac. Sci., Univ. Istanbul (A)* **19,** 8–12, 1954.

The pressure distribution on the surface of a shell (plane, circular cylinder, or sphere) associated with the acoustic radiation generated by the motion of the shell is investigated. Several elementary results are obtained and are used to deduce an appropriate Green's function by which the surface pressure on a cylindrical shell due to an arbitrary shell motion may be represented.

From author's summary by L. M. Milne-Thompson, England

3232. Kuttruff, H., and Thiele, R., The frequency dependence of acoustic pressure in rooms (in German), *Akust. Beihefte* **2,** 614–617, 1954.

Present paper reports the measurement of the frequency response with stationary excitation in 19 rooms under different conditions. The evaluation of 30 frequency curves in the range from 70 to 4000 cps gave the result that the mean level difference between successive maxima and minima amounts to 9. . .10 db, irrespective of volume of the room or reverberation time. The total number of the maxima, determined in the same frequency range, is within a mean fluctuation of 10% proportional to the mean reverberation time. The frequency irregularity calculated from these two values is consequently also proportional to the reverberation time.

From authors' summary

3233. Richards, E. J., Thoughts on future noise suppression research, *Proc. 3rd AGARD Gen. Assembly,* AGARD AG6/P3, 41–46, Sept. 1953.

3234. Tyler, J. M., Handling jet engine noise data, *Noise Control* **1,** 2, 46–49, Mar. 1955.

Ballistics, Detonics (Explosions)

3235. Gardner, G. W. H., Guided missiles, *Chartered mech. Engr.* **2,** 1, 5–22, Jan. 1955.

This paper is merely a popular introduction to the field of guided missiles. Since the author mentions military aspects, reviewer believes that more emphasis should have been given to multistage rocket developments, using the Rheintochter R-1 to R-3, the Rheinbote, and the A-9 with A-10 as fundamental examples for strategic rockets and missiles. Paper refers to Larynx, HS 293, FX 1400, X-4, V-1, and V-2, although there were more recent data publicly available on Vickers-Armstrong E 24/43, Fairey. Convair 774, and Viking missiles.

The physical fundamentals, propulsion methods, and guidance methods are well illustrated. Final part of the paper presents interesting information on TRIDAC (three-dimensional analog computer) and the guided-missiles facilities at Woomera in Australia.

C. R. Bell, USA

3236. Hudson, G. E., The deformation of a thin material shell of non-uniform thickness by a detonation wave, *Comm. pure appl. Math.* **7,** 1, 207–222, Feb. 1954.

A thin semi-infinite shell (or liner) of weak material is deformed by pressure exerted on it by a plane detonation wave running along the shell. The wave is assumed normal to the initial plane of the liner. The supposition of a tangential transition from the initial plane to the deformed surface seems to be not quite evident as it is not in agreement with the sudden momentum change occurring when a liner particle enters in the wave.

F. Schultz-Grunow, Germany

3237. Penzien, J., Experimental investigation of the blast loading on an idealized structure, *Proc. Soc. exp. Stress Anal.* **11,** 2, 91–106, 1954.

Soil Mechanics, Seepage

(See also Revs. 3100, 3256)

3238. Remson, I., and Fox, G. S., Capillary losses from ground water, *Trans. Amer. geophys. Un.* **36,** 2, 304–310, Apr. 1955.

General equation by L. A. Richards (1931) for steady-state, vertical flow in isotropic, homogeneous soils is combined with linear or hyperbolic relationships between capillary conductivity and capillary potential (as indicated by test data) to obtain equations relating capillary water loss (in equilibrium with evaporation), depth-to-ground-water table, and capillary potential.

Comparison between computed and measured values in a controlled soil tank indicates such equations may be used to estimate capillary losses from ground water bodies provided equilibrium is established and the soil is not too dry.

G. A. Leonards, USA

3239. Stanley, D. R., Sand filtration studied with radiotracers, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 592, 23 pp., Jan. 1955.

Sufficient fundamental information concerning the mechanisms involved in the removal of suspended particles from water by rapid sand filters has not been available to make possible other than a largely empirical and sometimes wasteful approach to their design. The present study was greatly facilitated by the development of methods and equipment for using radioactive tracers for studying these fundamental processes. Experiments were conducted to investigate several of the more important variables involved in the operation of rapid sand filters. Formulas expressing some of these variables are presented and methods of investigating others are suggested. From author's summary

3240. von Engelhardt, W., and Tunn, W. L. M., The flow of fluids through sandstones (translation from German by P. A. Witherspoon), Div. State Geological Survey, Ill. Dept. Registration and Education, Urbana, Ill., Circ. 194, 1955.

Paper presents results of experiments concerning fluid flow through samples of clayey sandstones (clay content, 1 to 5%). Data show that the Darcy equation holds for air, carbon tetrachloride, and cyclohexane. The permeabilities of the same samples when computed from the results of tests using water and several different salt solutions as the fluids are much lower. The computed permeability varies as the salt concentration changes. Moreover, the computed permeability of a given sample, using water or salt solution as the fluid, was found to vary as the pressure differential used in the experiment was changed.

Writers conclude that the interaction between the fluid and the clay fraction changes the effective size of the pore spaces through which the fluid passes, consequently changing the permeability. Seven tables summarize the results of the experiments. Possible application of results to oil production is mentioned.

R. G. Kazmann, USA

3241. Shekhtman, Yu. M., Determination of discharge of percolating fluid under conditions of silting (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **98,** 3, 549–552, Oct. 1954.

Paper considers the problem of one-dimensional downward seepage through a layer of soil when the percolating water contains suspended matter. This results in silting. Constant head is assumed, and the pressure of emerging water is taken as atmospheric. As silting progresses, the coefficient of permeability decreases, being at all times the smallest at the top. Since the discharge, which decreases with time, must at any particular instant be the same at all levels, the continuous flow of water gets broken at some depth, below which the water divides into separate streams flowing under a unit gradient. The level at which this separation takes place moves gradually upward.

The solution of this complicated problem, utilizing the results of a previous investigation by the same author and requiring the use of successive approximations, is outlined, and some theoretical values are plotted in comparison with experimental ones obtained by a different investigator.

A. Hrennikoff, Canada

3242. Heinrich, G., Expanded theory for ground water flow (in German), *ZAMM* **34,** 8/9, 335–337, Aug./Sept. 1954.

An abstract of a paper, to be published elsewhere, on a generalized formulation of Darcy's law for seepage flow in homogeneous anisotropic soils. O. Hoffman, USA

3243. Kohler, K., Bearing capacity of foundations (in German), *Bautechnik* **32,** 1, 1–3, Jan. 1955.

Author evaluates the integral of the vertical components of elementary friction forces acting along sliding curves which form a wedge beneath a strip footing. The equation of the sliding surface is furnished by using the condition that the integral has to be a minimum and that the angle in the axis between the tangent and the direction of force is known. The original stresses in the ground are supposed to be hydrostatic; the weight of the sliding wedge has been neglected; thus author deviates considerably from accepted procedures. This is the cause, in reviewer's opinion, of numerical values for bearing capacity being very small. Author considers the values corresponding to points in the pressure-settlement curve, where the radius of curvature is very small but equilibrium still prevails and bearing capacity is not exhausted. A. Kézdi, Hungary

3244. Rowe, P. W., A soil pressure gauge for laboratory model research, *Proc. Amer. Soc. civ. Engrs.* **80,** Separ. no. 569, 8 pp., Dec. 1954.

A soil pressure gage 1.50-in. diameter is described, suitable for pressure ranges 0.01 to 0.50 psi. The gage is free of error due to soil arching and zero wander, and is particularly suitable for investigating the distribution of soil pressures on laboratory models of structures. From author's summary

3245. Takagi, S., Physics of consolidation, *Rep. Inst. Sci. Technol. Tokyo* **8,** 5, 221–234, Oct. 1954.

During an attempt to systematize the theory of consolidation on the assumption that the deformation of clayey material obeys the law of isotropic elasticity, the physical background of Biot's theory of three-dimensional consolidation [*J. appl. Phys.* **12,** p. 155, 1941] has become clear. The fundamental equations are constructed directly for the system of clay particles, whose pores are saturated with water. The external force which plays the essential part in the process of consolidation is the frictional traction between water and particles. The equation of excess hydraulic pressure is similar to the equation of conduction of heat only in one-dimensional consolidation under steady surcharge.

The constancy of the *modulus of volume change,* introduced by Tschebotarioff ["Soil mechanics, foundations and earth pressure," 1952, p. 105], signifies the isotropic elasticity of the material. Its constancy, however, cannot be secured for clays, and the assumption of isotropic elasticity does not hold well for clayey foundations, though Terzaghi's theory of consolidation is based on this assumption. It is evident that systematic research is necessary to establish a theory of three-dimensional consolidation.

From author's summary

3246. Mogami, T., and Yamaguchi, H., The theory of the dynamical consolidation. I, *Rep. Inst. Sci. Technol. Tokyo* **8,** 5, 209–219, Oct. 1954.

Some theoretical analyses are executed on the one-dimensional consolidation of soils. Main results obtained are as follows:

(1) The occurrence of resonance can be expected in settlement

by consolidation when the soil is rather more elastic and has less viscosity.

(2) The effect of dynamical loading on the consolidation of clay with high solid viscosity cannot be deduced analytically in so far as we are contending with the simple assumption herein considered.

(3) The suction effects caused by the negative pressure are very predominant in shortening the time of consolidation.

From authors' summary

3247. Jacoby, E., Load distribution on piles of grillages (in German), *Bauingenieur* **29**, 2, 47–50, Feb. 1954.

3248. Soil density and stability, *Nat. Res. Counc. Highway Res. Bd. Bull.* 93, 64 pp., 1954.

This bulletin presents five papers containing useful and important information on the compaction of soils. The first, "Selection of densities for subgrades and flexible-base materials," by C. McDowell, recommends a "compaction ratio" (instead of percent compaction) in selecting soil densities. Ratio indicates the relative compaction between dense and loose states. Details are presented on preparation of soils, compaction test procedure, and use of compaction ratio.

The second paper, "Relationship between density and stability of subgrade soils" by H. B. Seed and C. L. Monismith, presents comprehensive test data and discusses effects of increase in density on soil stabilities. Effects of different compaction methods (static, impact, and kneading) and different measures of stability (CBR, Hveen Stabilometer, and triaxial test) are analyzed. Important effects of degree of saturation are also shown.

The third paper, "Effect of compaction method on stability and swell pressure of soils" by H. B. Seed, R. Lundgren, and C. K. Chan, gives test data and results for two soils using three compaction methods (see second paper). Comparisons of laboratory and typical field compactions show best agreement for kneading-type compaction. Stabilities and swell pressures on saturation varied greatly, depending on the method of compaction.

The fourth paper, "New method for measuring in-place density of soils and granular materials" by C. E. Minor and H. W. Humphreys, discusses, first, the shortcomings of presently used methods for measuring hole volumes to determine in-place soil densities. A "Washington Densometer" has been developed and claimed to overcome these shortcomings. Device uses a rubber balloon inflated with fluid, a closed calibrated system with cylinder and piston, and rings of known volume to extend measurements. In use it has proved to be faster, equally or more accurate, and more versatile than other types now employed.

The fifth paper, "Effect of repeated load application on soil compaction efficiency" by G. F. Sowers and C. M. Kennedy, III, analyzes factors causing different densities due to various methods of applying the same compactive effort (energy). Most important factor is found to be percentage of total energy which was applied in each application. The smaller the number of applications required to apply the same total amount of energy, the greater was the resulting density. G. J. Tauxe, USA

Micromeritics

(See also Rev. 3261)

3249. Forscher, F., Analysis of continuity of one phase in a powder mixture of two phases, *J. Franklin Inst.* **259**, 2, 107–114, Feb. 1955.

Paper contains a theoretical analysis of the continuity of one phase (powder A) in a mixture of two powders (A and B). It is assumed that the two powders are well mixed so that particles of powder A are randomly distributed in powder B. The continuity condition of powder A is expressed by the probability that the separation between two particles of this phase vanishes. For spherical particles of unequal sizes the continuity condition can be stated as the probability that the distance between the centers of any two particles of powder A equals the sum of their radii.

General equations are developed and a powder mixture of equal spherical particles is discussed as a special case.

From author's summary

3250. Pattantyus, G., Pneumatic conveying, *Acta Techn. Hung. Budapest* **8**, 1/2, 129–177, 1954.

The first part of this paper is a synopsis of results hitherto obtained in theoretical and experimental research for the precise development of the theory of pneumatic transportation of materials. Results of a series of experiments made on grain conveying at the Hydraulic Machine Laboratory of the Technical University (Budapest) are explained in detail. The aim of these experiments was to elucidate the course of dynamic, aerodynamic, and energetic processes which take place in horizontal and vertical conveyor pipes. The scientific research work was conducted by the author's collaborator, L. Pápai, who partly refuted, partly supplemented the statements of the Gasterstädt theory prevailing in practice. By the introduction of the concept "degree of efficiency" and by the establishment of the principles of economical design, Pápai's theory of pneumatic grain conveying has been raised to a scientific level. This theory yields directly utilizable results for grain transported by suction in engineering practice. For designing cinder and fly-ash conveyors for big power plants, measurements require further supplementation. The research conducted by L. Pápai and Cs. Fáy throws light on the kinetic importance of the lower limit of air velocity insuring safe material transport and of the limit velocity of the state of suspension.

Courtesy of Hungarian Technical Abstracts

3251. Koyama, R., The flow and friction of powder, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 29–31.

Geophysics, Meteorology, Oceanography

(See also Revs. 3099, 3194, 3239, 3240)

3252. Němec, A., Geomechanics. On forces forming the surface of the earth [Geomechanika. O silách, které formují povrch zemský], Bratislava, University Press, 1947 (2nd ed., 1953), 216 pp., 74 illus.

One of the basic textbooks on geomechanics with thorough discussion of forces forming and affecting the surface of the earth and their mechanical and mathematical relationships. It is a new presentation of principles described in the author's book "Life of the earth," 1936. Three basic mechanical forces acting upon solid and fluid masses of the earth—gravity, centrifugal, and circulating forces—are discussed and mathematically interpreted in chapters under following titles: IV. The shape of our earth, its specific gravity, thickness of solid surface (lithosphere), variation of temperature with the depth, fluid surface, steel core. V. Gravity forces, problem of gravity forces in a hollow sphere, spherical strata of earth, and their mechanical relationships. VI. Isostasy (application of Archimedes' law to conditions of floating

earth surface and mathematical relationships), Airy's and Pratt's isostasy. VII. Tangential forces. Analysis of centrifugal forces due to rotation and circulation, ocean currents in Arctic and Antarctic. VIII. Flow of fluid masses, effect of pulsation of gravity forces on the atmosphere, effects of winds on ocean currents (Labrador, Gulf). IX. Endogenous effects and forces. X. Orogenous forces. XI. Synclinal surfaces and their origin. XII. Epeirophoresis (movements of solid surface). XIII. Movement of poles during geologic growth of the earth. XIV. Origin of continents and oceans. XV. Differences in gravity forces, their mathematical relationships and laws. XVI. Earthquakes, volcanism, hot springs, geysers. XVII. External effects of forces (ectogenous and oxogenous forces) of organic and inorganic origin. Atmosphere, hydrosphere, biosphere; water, its properties and forms, effects on minerals, gases, its thermal and biologic properties. Effect of water on civilization and culture. References are made to research and publications by L. Čepek, L. Kettner, Harmann, Kaiser, Kober, Siemroth, Wegener.

The book presents basic principles of geophysics in relation to dynamic forces. Relations between the features of the earth and agencies producing them are expressed by laws of mechanics, of special interest for study, research, and work in various fields of geology, climatology, cosmogony, hydrography, meteorology, oceanography, terrestrial magnetism, seismology, etc.

J. J. Polivka, USA

3253. Němec, A., Dynamic equilibrium of the earth—the solution of the crisis in geophysics [Dynamická rovnováha země—východiskem z krise geofysiky], Bratislava, University Press, 1954, 10 pp., 16 illus.

The author substantiates his opinion that the exclusive application of the potential theory to solve all problems of geomechanics (see preceding review) made it impossible to solve the problems relating to dynamic equilibrium of the earth, and that very often the solution is based on hypotheses which cannot be corroborated by physical laws. His opinion has been confirmed by V. A. Magnickiy, professor at Moscow University, in his recent book, "Fundamentals of geophysics," 1953. He criticizes especially isostatic hypotheses and refers to two different presentations of inhomogeneity of the earth surface (Airy and Pratt). On the basis of the fact that one half of gravitational acceleration is caused by masses filling the space of the tangential sphere whose diameter is equal to the radius of the earth, it can be proved that the inhomogeneity of the earth surface does not affect the gravitational acceleration, no matter whether Airy's or Pratt's theory is assumed, if the earth surface is in statical equilibrium. For this reason the very often used reduction of the gravitational acceleration of Bouger contradicts the principle of static equilibrium. Cascade forces cause tidal waves which, in accordance with statical theory of geophysics, are calculated to be $31^1/_2$ in. Assuming dynamic equilibrium, the maximum tidal wave is 72 in. high, which corresponds with reality.

The author discusses the effects of orogenous forces, movement of the poles, epeirophoresis, and concludes: The described chain of interlocked facts is based on dynamic equilibrium of the inhomogeneous surface of the earth. This equilibrium is caused by three cascade forces normal each to the other: (a) equilibrium of vertical forces indicates gravitational deviations, which are in connection with transgression and regression of the seas, i.e., movements of continents in the vertical sense by hundreds of feet; (b) equilibrium of meridial forces as origin of "alpine" orogeny and of movement of the poles; (c) equilibrium along the parallels, instrumental for the discovery of orogenies along the meridians (Cordilleras, Ural), which primarily causes the epeirophoresis.

Final conclusions: (1) It is the task of geophysics and geochemistry to serve as basis for correct conception of geological development of the earth; (2) the knowledge of pertinent laws will contribute to successful solution of cosmogenic problems; (3) complex mechanical analysis (not only statical but also dynamical) of equilibrium of the earth will fulfill all requirements expected from geophysics.

J. J. Polivka, USA

3254. Otuki, Y., A few comments on design seismic force distribution, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 367–369.

Distribution of seismic force is considered to be based on dynamic aspects, since an earthquake is supposed to be ground motion of a vibrational nature. Introducing an X-type frequency spectrum, it is shown that, by incorporating this principle, the seismic design force can be safely reduced for flexible tall buildings. Further, a nonrigid soil is disadvantageous for both rigid and flexible buildings, but is advantageous in that it relieves the base shear for relatively heavy buildings. Author is of the opinion that soil nature must be considered in relation to mass, moment of inertia, and stiffness of structure. It is dangerous to make a low building flexible or a certain particular floor flexible, since phase reversal may cause an excessive deformation in the structural materials, which naturally would collapse if they are brittle. Also, excessive deformations may cause a very large eccentric moment in building columns due to the vertical load which is always neglected in a seismic design.

S. K. Ghaswala, India

3255. Tuboi, Y., and Tajimi, H., On the rocking vibration of a structure, *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 329–331.

Paper describes phenomenon of rocking vibration taking place during an earthquake. This is found to be linear initially, but curved later, and whose nature is closely dependent on the soil condition supporting the structure. The base of rigid structures subjected to horizontal motion follows rotation such that the location of rotation center at yield reaches as far as the edge of structure when the soil is stiff and only 80% of half width for soft soils. Paper forms a supplementary guide to that by Otuki (see preceding review).

S. K. Ghaswala, India

3256. Wechmann, A., Elaboration of hydrologic data [Auswertung gewässerkundlicher Messergebnisse], Berlin, Verlag Technik, 1952, 99 pp. DM 10.

This concise manual deals with computation of results of observations, accentuating statistical methods: correlation, frequencies, duration, accumulation. Construction of different diagrams is explained: chronological charts, frequency and duration curves, storage diagrams. Probability of hydrologic data is discussed. Construction of discharge curve and simple computation of its equation is presented; nomograms are suggested. However, methods of elaboration of discharge measurement are not included in this work. Author, former director of Prussian Hydrologic Institute, presents in this valuable booklet the modern methods applied in Germany.

S. Kolupaila, USA

3257. Davies, D. R., On diffusion from a continuous point source at ground level into a turbulent atmosphere, *Quart. J. Mech. appl. Math.* **7**, part 2, 168–178, June 1954.

Problem is to determine the steady-state distribution of smoke

emitted from a fixed point source at ground level. The method used by Calder [AMR 3, Rev. 2015] for an infinite line source is extended to three dimensions. Following Calder, a power law is assumed for the mean wind distribution in the vertical and for the vertical diffusivity. The coefficient of lateral diffusivity is defined by assuming an arbitrary power law of the coordinates and then choosing the particular values of the indexes which render the diffusion equation soluble under the required boundary conditions. Such a coefficient is found which can be justified physically. The results for the cloud height and width agree well with values observed under conditions of neutral stability, which, the reviewer believes, well justifies the method as an approach to the practical problem. R. P. Pearce, Scotland

3258. **Inoue, E., A note on the interrelation between two types of turbulent diffusion in the atmosphere,** *Proc. 2nd Japan nat. Congr. appl. Mech.*, 1952; Nat. Committee for Theor. appl. Mech., May 1953, 227–228.

3259. **Ibing, R., Flow of flue gases downstream of the chimney above flat surroundings** (in German), *ZVDI* **96**, 32, 1085–1090, Nov. 1954.

Wind-tunnel tests on a model of a standard power station are described in which the flow conditions around the model were visualized by means of a thread probe and tobacco smoke issuing from the chimneys. The effects of direction of wind, wind velocity, flue-gas exit velocity, and chimney height were studied qualitatively, using photographs to show the influence of these factors on the smoke plume. It is concluded that: (a) The long axis of the largest building should be normal to the prevailing direction of the wind; (b) if the station is built in steps of decreasing height, the lowest building should be nearest the wind; (c) the ratio between the heights of the chimney and the tallest building should be between 1.7 and 2.0, and the influence of nearby cooling towers must not be neglected; and (d) the ratio of flue gas to wind velocity should be about 2; but at very low wind velocity (summer, fog), dust nuisance near the power station cannot be avoided even with very high gas velocities and tall chimneys. K. R. Lenel, England

3260. **Hewson, E. W., Stack heights required to minimize ground concentrations,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-211, 17 pp.

Aerodynamic and meteorological concepts are combined in a procedure for estimating ground concentrations of effluents from stacks with various possible heights and exit gas velocities. The operation of each of the several influences at work is first described. A detailed example is then given of how the most important phases were integrated into a consistent procedure for predicting ground concentrations in answer to a specific design problem. Further improvements and refinements of the method are desirable and are being incorporated in a later study.

From author's summary

3261. **Bodurtha, F. T., Jr., A technique for the rapid solution of an air-pollution equation,** ASME Ann. Meet., N. Y., Nov. 28–Dec. 3, 1954. Pap. 54—A-187, 10 pp.

A technique for the rapid solution of the Bosanquet and Pearson formula for atmospheric gas concentrations is developed in this paper. The equations and graphs presented refer to stack gases at or near atmospheric density. General consideration is given to stack gases whose density differs from atmospheric. It is indicated that the total plume rise may decrease with increasing stack gas velocity when the effluent density is less than atmospheric. From author's summary

3262. **Woodruff, N. P., and Zingg, A. W., A comparative analysis of wind-tunnel and atmospheric air-flow patterns about single and successive barriers,** *Trans. Amer. geophys. Un.* **36**, 2, 203–208, Apr. 1955.

Atmospheric wind velocities were measured aft of a single and a series of three successive snow fences and compared to velocities measured aft of models of the fences placed in a wind tunnel. Results indicate the wind-tunnel approach gives a reasonable estimate of the effectiveness of full-scale surface barriers under atmospheric conditions. It is also shown that a series of three successive barriers is not enough to obtain a beneficial accumulative ground effect. A general lessening of velocity with distance traveled over the successive barriers indicates, however, that an accumulative effect might be obtained in a system containing a larger number of successive barriers extending for a great length. The barriers are shown to increase the velocity fluctuations of the wind from two to nine times at different locations aft of a single barrier. Maximum fluctuations in a series of successive barriers were found to occur at the 0.5-ft elevation aft of the second barrier.

From authors' summary

Lubrication; Bearings; Wear

(See Rev. 3017)

Marine Engineering Problems

(See Rev. 3128)